AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

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CCXCII.

(Vol. XIII.—November, 1884.)

ANALYSIS OF THE RAINFALL AT LAKE COCHITUATE, MASS., 1852–1883.

By DESMOND FITZGERALD, M. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION, JUNE 10TH, 1884.

WITH DISCUSSION.

As many errors have been observed in statements of the rainfall on the Cochituate water-shed, the writer has been induced to make the following analysis, taken from the official records. The water from Lake Cochituate was first used for the supply of the city of Boston in 1848, but it was not until 1852 that a continuous series of observations on the rainfall was begun.

The standard gauge used is one with a diameter of 14.85 inches, in which 1 inch of rain weighs 100 ounces. The results are obtained by weighing after each storm.

The elevation of the gauge is 2½ feet above the ground.

The table given herewith contains the monthly amounts in each year, with a division into seasons, and from this table all the data contained in the diagrams are obtained:

TABLE OF RAINFALL—LAKE COCHITUATE.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December	Spring.	Summer.	Autumn.	Winter.	Total.
1852	5.80	1.76	4.42	9.60	2.60	2.00	2.10	8.27	2.04	3.40	2.76	3.12	16.62	12.43	8.20	10.68	47.93
1853	3.68	6.56	2.92	3.80	6.32	0.56	2.84	7.20	5.44	4.56	5.26	6.59	13.04	10.60	15.26	16.83	55.73
1854	2.45	5.16	4.16	5.60	3.92	2.08	2.32	0.28	3.68	3.37	7.79	2.34	13.68	4.68	14.84	9.95	43.15
1855	4.52	3.50	1.91	2.65	0.82	1.98	3.86	0.77	0.75	4.16	4.84	5.20	5.38	6.61	9.75	13.22	34.96
1856	1.44	0.22	0.66	4.27	7.81	1.77	1.76	11.40	3.13	2.34	1.43	4.57	12.74	14.93	6.90	6.23	40.80
1857	2.51	1.30	1.72	10.23	7.15	4.02	8.85	6.62	4.27	7.06	3.07	6.30	19.10	19.49	14.40	10.11	63.10
1858	2.61	3.32	3.87	4.39	2.23	10.17	3.46	6.42	5.17	2.12	2.91	1.99	10.49	20.05	10.20	7.92	48.66
1859	5.64	2.91	10.95	1.37	3.46	3.16	0.99	7.69	4.56	0.33	3.55	4.41	15.78	11.84	8.44	12.96	49.02
1860	1.24	3.80	1.98	2.25	1.98	11.16	6.82	4.89	9.92	1.72	5.97	3.71	6.21	22.87	17.61	8.75	55.44
1861	2.51	3.81	2.75	6.44	3.12	2.64	1.62	7.79	2.76	3.20	6.20	2.60	12.31	12.05	12.16	8.92	45.44
1862	7.82	1.08	4.18	1.85	2.71	6.58	6.54	1.43	2.62	4.83	7.69	2.36	8.74	14.55	15.14	11.26	49.69
1863	4.10	4.38	3.57	11.34	2.66	1.98	14.12	5.61	3.39	4.56	8.54	5.05	17.57	21.71	16.49	13.53	69.30
1864	3.37	0.98	8.44	4.02	2.84	0.58	1.06	3.56	1.52	6.50	5.45	4.28	15.30	5.20	13.47	8.63	42.60
1865	4.99	4.45	5.48	2.18	8.25	0.91	3.10	3.36	1.66	6.99	4.78	3.31	15.91	7.37	13.43	12.75	49.46
1866	1.44	5.80	3.92	1.94	6.46	4.80	13.35	3.98	8.36	3.43	4.52	4.32	12.32	22.13	16.31	11.56	62.32
1867	2.76	5.40	5.65	2.13	6.46	2.95	5.36	12.36	1.08	7.27	2.63	1.90	14.54	20.67	10.98	10.06	56.25
1868	3.70	1.18	2.51	5.61	8.12	2.95	2.16	7.38	7.69	1.19	6.77	0.45	16.24	12.49	15.65	5.33	49.71
1869	3.71	7.07	7.52	2.57	7.59	3.68	2.63	2.34	8.49	9.50	3.26	5.98	17.68	8.65	21.25	16.76	64.34
1870	7.85	4.68	6.04	8.81	3.14	4.05	3.10	2.03	0.64	7.96	4.40	3.19	17.99	9.18	13.00	15.72	55.89
1871	1.31	2.30	5.02	2.29	5.66	5.96	2.20	3.56	1.46	5.38	7.01	3.24	12.97	11.72	13.85	6.85	45.39
1872	1.86	1.37	3.06	1.74	3.24	4.27	5.55	9.76	6.29	3.69	4.22	3.42	8.04	19.58	14.20	6.65	48.47
1873	4.24	2.43	3.98	2.69	3.24	0.38	4.08	7.17	2.62	6.11	4.54	3.93	9.91	11.63	13.27	10.62	45.43
1874	2.96	2.90	1.19	6.36	3.40	4.79	5.16	4.83	1.55	1.04	2.05	1.70	10.95	12.78	4.64	7.56	35.93
1875	2.42	3.15	3.74	3.23	3.56	6.24	3.57	5.53	3.43	4.85	4.83	0.94	10.53	15.34	13.11	6.51	45.49
1876	1.83	4.21	7.43	3.24	2.80	1.60	9.49	2.19	3.98	2.00	6.59	3.13	13.47	13.28	12.57	9.17	48.49
1877	3.19	0.53	7.79	3.24	3.73	2.64	2.77	3.35	0.46	8.14	6.94	1.02	14.76	8.76	15.54	4.74	43.80
1878	5.77	5.93	4.20	5.63	0.83	3.33	3.47	6.94	1.12	5.15	6.09	5.12	10.66	13.74	12.36	16.82	53.58
1879	2.00	3.05	3.90	4.69	1.20	4.14	3.38	6.43	1.74	0.90	2.98	3.60	9.79	13.95	5.62	8.65	38.01
1880	3.07	4.05	2.83	2.94	2.03	1.25	7.00	3.81	1.69	2.95	1.70	2.56	7.80	12.06	6.34	9.68	35.88
1881	5.56	4.43	4.79	1.71	3.18	4.83	2.78	1.13	2.13	2.87	3.85	3.83	9.68	8.74	8.85	13.82	41.09
1882	5.93	3.96	2.76	1.89	4.73	1.87	3.49	1.14	9.20	2.22	0.93	2.17	9.38	6.50	12.35	12.06	40.29
1883	2.88	3.59	1.76	2.27	3.95	1.81	2.88	0.39	1.31	5.16	2.06	3.14	7.98	5.08	8.53	9.61	31.20
Av.	3.60	3.41	4.22	4.16	4.04	3.47	4.37	4.99	3.57	4.22	4.55	3.42	12.42	12.83	12.33	10.44	48.02

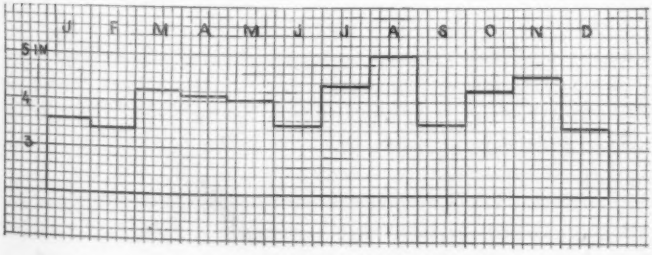
The same method of analysis has been pursued as that adopted by Mr. Chas. A. Schott in his excellent treatise on the rain and snow in the United States, published among the "Smithsonian Contributions to Knowledge."

The monthly averages for the whole period of 32 years at Lake Cochituate are as follows:

MONTHLY AVERAGE RAINFALL—32 YEARS.

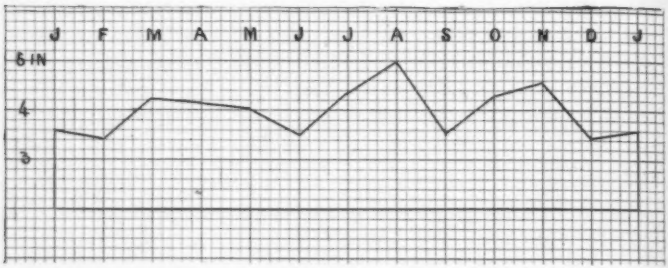
January	3.60
February	3.41
March	4.22
April	4.16
May	4.04
June	3.47
July	4.37
August	4.99
September	3.57
October	4.22
November	4.55
December	3.42

These averages are plotted graphically in the following diagram:



which gives to the eye the relative values of the different months better than in the form of a continuous profile.

If, however, it is wished to trace the progress of the annual fluctuation in the rainfall, it can be done by a profile of the following form, which contains the same results as diagram No. 1:



As will be seen, the period of low rainfall is in the winter months, while the month of maximum rainfall is August. June and September are months of low rainfall, and there is a rise in the profile during the spring months and late in the autumn.

That the variation in the distribution of the annual rainfall is, however, not very great in amount, may be seen by an inspection of the rainfall occurring in the four seasons of the year:

Spring	gives	12.42	inches.
Summer	"	12.83	"
Autumn	"	12.33	"
Winter	"	10.44	"

The question now arises, is this distribution, indicated in the above diagrams, a permanent one, or is it accidental only?

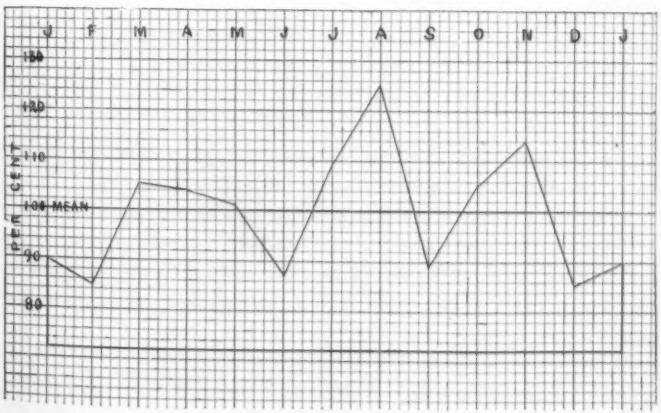
An examination of the records of precipitation along the entire coast from Portland to Washington will show a decided maximum during the summer months and a minimum in winter. If Mr. Schott's type-curve for the Atlantic seaboard be compared with the Cochituate profile, it will be seen that they agree very closely. The opposite of this is true, however, for the Pacific coast, when the maximum occurs during the winter and the minimum in summer.

The following table gives the ratios of the observed monthly averages to the mean monthly rainfall. It is obtained by dividing each monthly average by the average monthly amount or mean for the whole period:

RATIOS OF OBSERVED MONTHLY TO MEAN MONTHLY RAINFALL.

	Per cent.
January	90
February	85
March	1 05
April	1 04
May	1 01
June	87
July	1 09
August	1 25
September	89
October	1 05
November	1 14
December	85

Diagram No. 3 gives these results in a graphical form:



and if a comparison is desired between the periods of ten years and the whole period, it may be done in terms of the monthly average by means of the following table:

TABLE OF MONTHLY VALUES IN TERMS OF THE MONTHLY AVERAGE.

1852–1861.		1862–1871.	1872–1881.
January	80	90	91
February	89	82	88
March	88	115	118
April	126	95	98
May	98	119	75
June	98	76	92
July	86	118	124
August	152	100	140
September	103	81	69
October	80	127	104
November	109	121	121
December	101	75	81

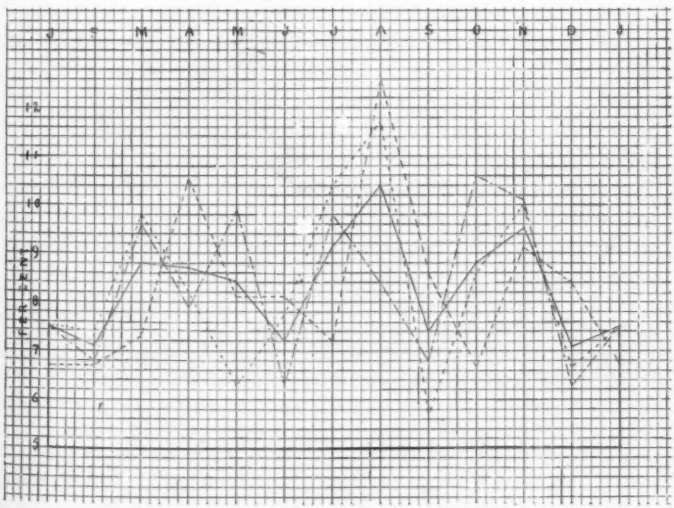
For purposes of comparison with other places, it will be of interest to express the monthly values in terms of the annual rainfall.

The average rainfall in the Lake Cochituate district has been, for the 32 years under consideration, 48.02 inches. Dividing the monthly averages by this amount, and shifting the decimal point, the following values are arrived at, first for the whole period, and then for periods of 10 years from 1852:

TABLE OF MONTHLY RATIOS TO THE ANNUAL RAINFALL.

	1852–1883.	1852–1861.	1862–1871.	1872–1881.
January.....	7.5	6.7	7.5	7.5
February.....	7.1	6.7	6.8	7.4
March.....	8.8	7.3	9.6	9.8
April.....	8.7	10.5	7.9	8.2
May.....	8.4	8.1	9.9	6.3
June	7.2	8.1	6.3	7.7
July.....	9.1	7.2	9.8	10.4
August.....	10.4	12.6	8.4	11.7
September....	7.4	8.6	6.8	5.7
October.....	8.8	6.7	10.6	8.6
November....	9.5	9.1	10.1	10.0
December....	7.1	8.4	6.3	6.7

The following diagram contains these values, the full line being the average for the whole period and the dotted lines the decades:



A cursory examination of this diagram will show the persistency of the maximum and minimum tendencies already referred to. The winter amounts agree remarkably well, even when the whole time is thus divided into decades. It will be noticed that the spring maximum is likely to occur in either of the spring months, and that the profiles all sink in the early summer and early autumn.

It is probable that this monthly distribution will be somewhat modified by a period of longer observation. Treating the observed values by an analytical process* of computation, we shall get a curve in which the irregularities are modified. According to Sir John Herschel, the elements may be considered:

1st. Independent of the others (or the mean).

2d. The extent and law of its deviation from that amount.

3d. Their mutual interdependence, or the reaction of each element on the rest.

The following is the formula as used by Mr. Schott:†

$R = A + B_1 \text{ sin. } (\Theta + C_1) + B_2 \text{ sin. } (2\Theta + C_2) + B_3 \text{ sin. } (3\Theta + C_3) +$ in which

R = rainfall in inches for any one month.

A = mean monthly amount.

B_1, B_2, B_3 = the parameter of its fluctuations for periods of 1, $\frac{1}{2}$, and $\frac{1}{3}$ year.

Θ = arc proportional to time and inversely proportional to the period (360°) or 30° for one month.

C_1, C_2, C_3 = angular constants having reference to the epochs of their respective periods.

Applying the above formula to the observed monthly averages, we obtain the following diagram:

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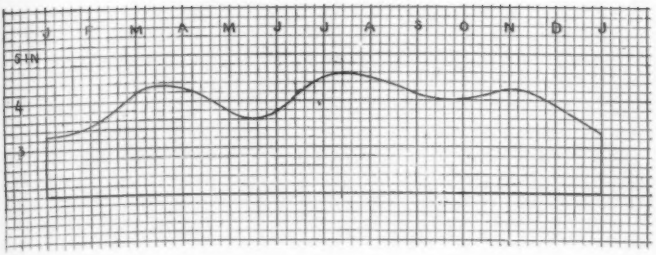
* Bessel's circular function.

† See Appendix to Coast Survey, 1876, No. 22; also article on Meteorology in the eighth edition Encyclopedia Britannica.

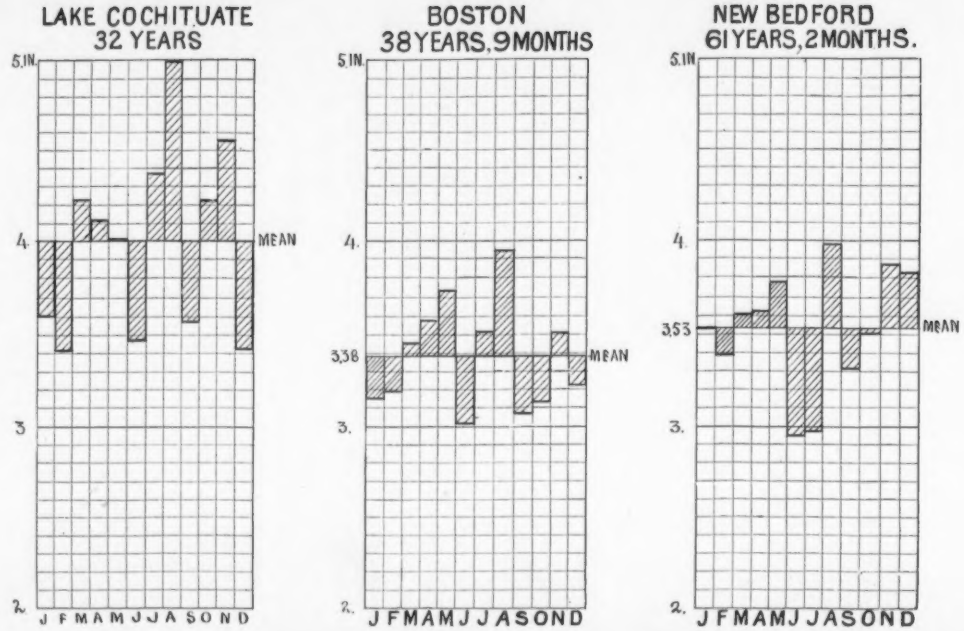


As it may be of interest to compare the Cochituate records with neighboring districts in which the rainfall has been observed for long periods, the following diagrams have been prepared, Plates XLVI and XLVII, showing the monthly distribution above and below the mean for Lake Cochituate, Boston, New Bedford, Providence, Gardiner and New York. All but the New York observations, which are from Dr. Draper's excellent reports, are from the Smithsonian Tables, second edition.

Fluctuations in the Annual Rainfall.

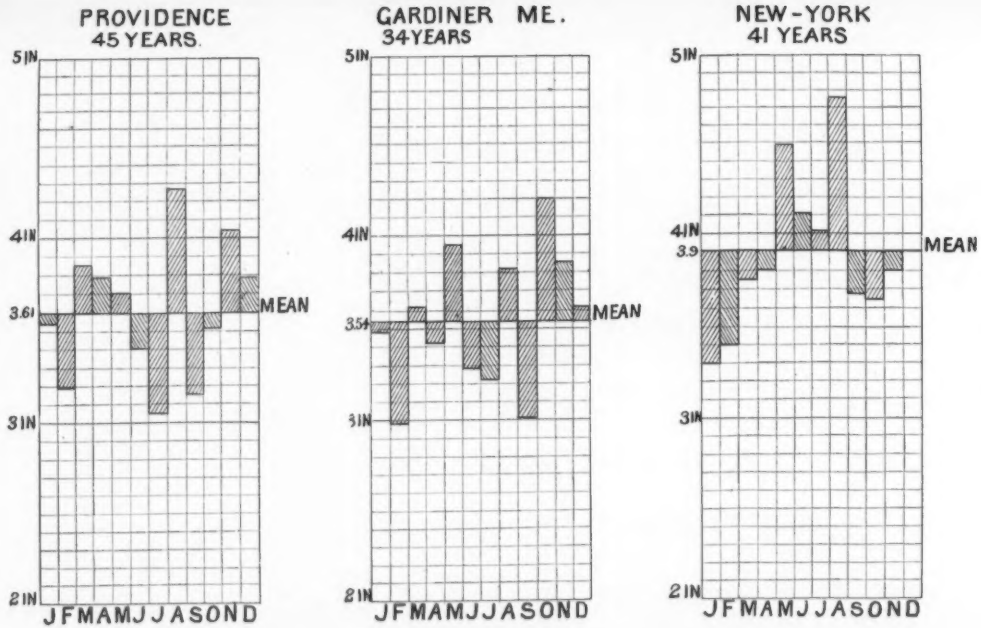
The remaining diagrams give the annual rainfall, first, in inches, Plate XLVIII, and second, in ratios to the mean, Plate XLIX. The period is almost too short from which to draw inferences in regard to any secular change. It is very commonly believed that the rainfall is decreasing, as the forests are cleared, and the diagrams show the last ten years to be years of very low rainfall, much below the mean; but previous to 1873 no such deductions can be drawn from the profile. An inspection of longer periods in other places does not reveal any decided permanent change one way or the other. The fluctuations in the annual rainfall are very irregular, and may or may not be subject to some regularity of distribution.

PLATE XLVI.



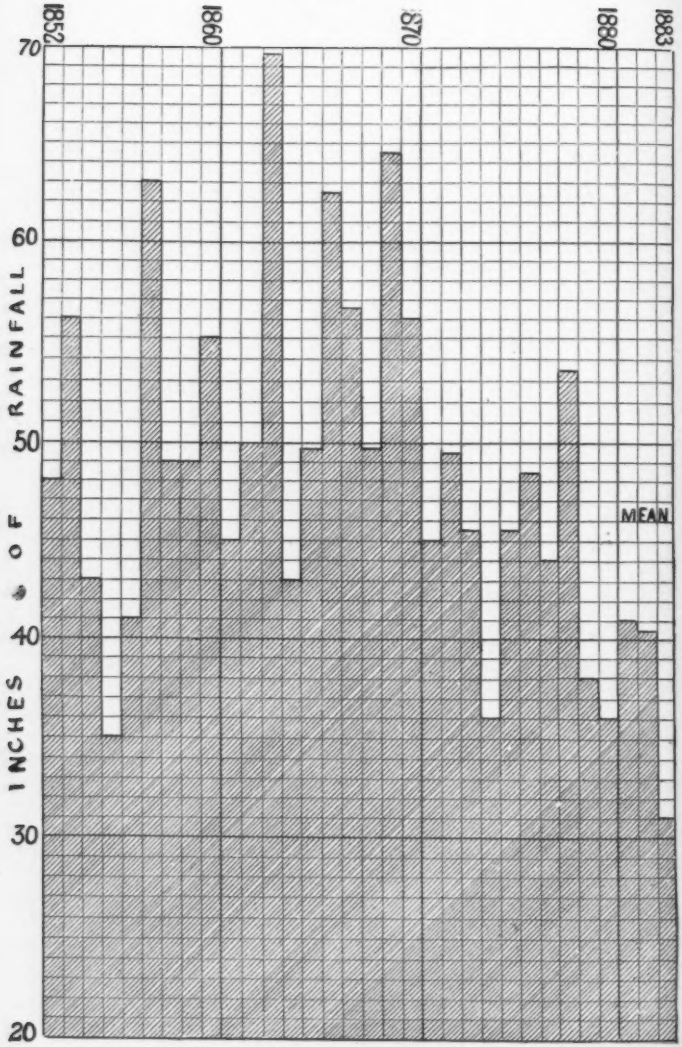
MONTHLY AVERAGES ABOVE AND BELOW THE MEAN.

PLATE XLVII.



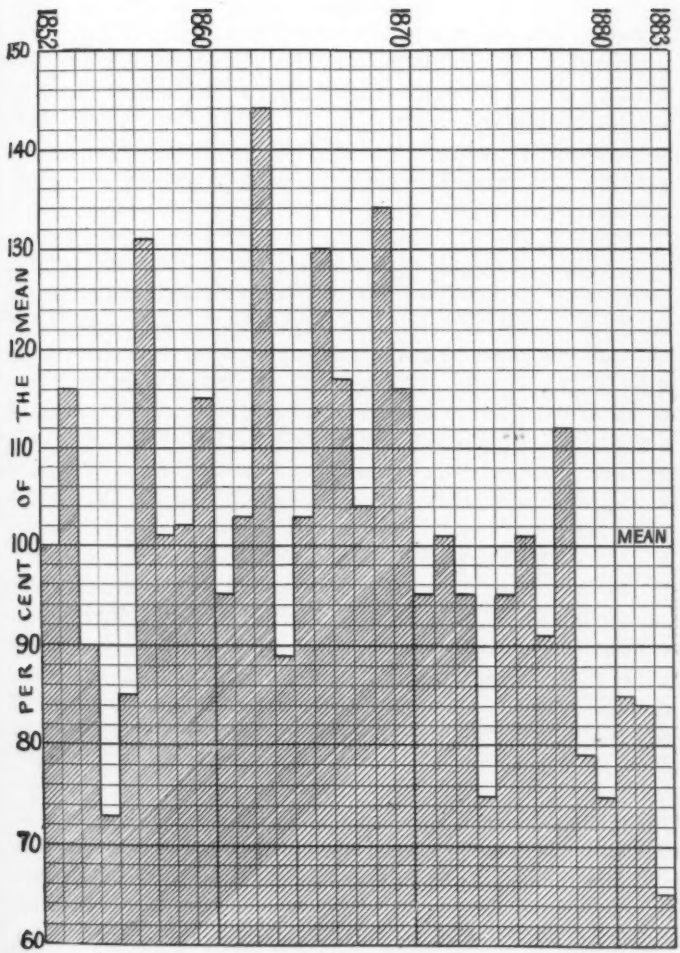
MONTHLY AVERAGES ABOVE AND BELOW THE MEAN.

PLATE XLVIII.



ANNUAL RAINFALL 1852-1883 IN INCHES.

PLATE XLIX.



ANNUAL RAINFALL, 1852-1883, IN PERCENTAGE OF THE MEAN.

DISCUSSION.

ROBERT FLETCHER, Assoc. Am. Soc. C. E.—I would like to present one or two facts coming to my notice on this subject, not in immediate connection with the rainfall on the Atlantic coast, but in the upper Connecticut valley. I am at present located at about midway up the Connecticut River on the New Hampshire line, and have been investigating recently the record of rainfalls since 1836. I have found a fact which has a bearing in connection with the recent discussions as to the variations in amount of rainfall in different parts of the country. The results collected for twenty years, from 1835 to 1854, show an average rainfall of about 41 inches for that part of the Connecticut valley. Mr. Schott's statistics and curves show that the curve of rainfall on the Connecticut valley makes a decided bend up the valley. I do not know as there is any theory to account for it; but it is a fact that in part of the valley the rainfall is greater than that east or west of the valley, on the same latitude. The period from 1863 to 1884 shows a diminution of nearly one-fourth in the annual rainfall; this second period of twenty years is separated by an interval of ten years from the first just referred to. These data were collected with great care. The data for the first twenty years by Professor Young, who was a very careful man, and the data for the last twenty years, from 1863 to 1884, have been collected at the observatory. There have been a few failures to take the observations during the dry season, but as near as we could get at the figures, which are substantially correct, the average for the first period of twenty years was about 41 inches. The average for the second period of twenty years would scarcely touch 31 inches. But bearing in mind the fact of the clearing of the forests in the upper portion of and throughout the valley, this fact regarding the rainfall may have some bearing, which will be developed in time.

CLEMENS HERSCHEL, M. Am. Soc. C. E.—I think it is well not to be alarmed in the matter of rainfall, especially not about the effect thereon of the removal of the forests. As the gentleman has spoken in reference to the upper Connecticut valley, I will say that I belong to that valley myself, and that I have explored it throughout its entire length. The point I wish to call attention to is simply this: that when ordinarily we hear about the forests having been chopped off, or the country having

been denuded, the truth of the matter will be found not to allow of any such expression being used, because the term, "the wood is all chopped off," is applied by the lumbermen as soon as they have chopped off all the white pine and all the spruce; but the forest remains there, and the appearance of the country is precisely the same, and it is practically in the same shape it was before. The country is covered with forests, when the stranger may hear the lumbermen talking about having no forests. There are the yellow birch and the white birch, and the maple and the rock maple, and all those hard-wood trees which cannot be rafted, and therefore are not chopped down, to say nothing about the underbrush, which is a potent factor in equalizing the flow of the rainfall from a certain district. The facts, as given this morning, are somewhat instructive on these points. Mr. Moore mentioned that the highest flood at St. Louis was in 1844, before there was any claim that the rainfall was being affected by the removal of forests, or that the chopping of the forests produced the floods. The same subject has been discussed in a paper by Col. Roberts, who shows that on the Ohio the forests have nothing to do with producing floods, or with influencing the rainfall. At the Washington meeting some years ago, Prof. Hilgard stated that the records of the rainfall at Marietta, O., which are the oldest and longest in existence in Ohio, show that the rainfall was not affected by the removal of the forests. Now, with all due deference to my friend and neighbor here, I will venture to say that there is something wrong, a screw loose somewhere, about that diminution of 10 inches rainfall in ten years. I know it is said that figures do not lie, but by taking a period of twenty years—all sorts of things can be gotten out of that short period—I do not say gotten designedly, but there is room for self-deception, and perhaps there is no way in which self-deception can be accomplished with better success than by statistics, and by this species of statistics. This may sound like an unkind thing to say, but we are on such good terms that my friend will not object. I wish only to say, as to the 10 inches diminution of rainfall in ten years being the effect of the forests, that I think there must be something wrong about it. The rainfall probably has not been affected in that way in the Connecticut valley.

Mr. FLETCHER.—I do not wish to be understood as saying that I believe the clearing of forests has any immediate influence on the rainfall,

but the figures were carefully collected. Wherever the mistake may be, if there is one, we do not find it. We have been suspecting that there is some influence of elevation upon the indications given. I have lately had rain gauges of two different patterns made, and kept at different elevations, and have already found, even in the course of three or four months of observation, that there is a decided difference in the indications. But the time has been so short, that I thought it was not worth while to say anything about it. It would, however, make a difference of only about 5 per cent. In regard to the depletion of forests in the Connecticut valley, I will say that immense reaches of forests have been cut off entirely. Mountains have been completely stripped to supply the railroads with fuel. For miles and miles in regions adjoining the tracks of the various railways in northern New England, you may see wood piled up sufficient for years of consumption.

Robert Moore, M. Am. Soc. C. E.—In confirmation of the views of Mr. Herschel, I desire to call attention to a fact in regard to the prairie States of the West—notably the State of Illinois.

As is well known to the residents of those States, the settlement of the country has been followed by an increase of the area covered by trees and forests. Trees have been planted for orchards, for ornamental purposes, for timber, and as a protection against the wind. The stoppage of prairie fires has also promoted the growth of trees on all uncultivated lands, until now dense thickets and clumps of trees are seen in every direction, where a few years ago not even a bush was in sight for many miles.

But this very marked change in the area covered by trees has not been accompanied by any change in the rainfall, which was abundant when there were no trees, and is no less abundant now. So that I doubt very much whether forests ever produce any appreciable influence, one way or the other, upon the amount of rain.

N. M. Edwards, M. Am. Soc. C. E.—I will add that in Wisconsin I have noted the records made by the United States Signal Service at several remote stations during a period of eleven years, as also data collected for evidence in the courts, and have observed a great variation in the average of extremes, June and December, but between them a uniform gradation. June, our month of greatest rainfall, averages three and one half times that of December.

The average per year during eleven years at these distant stations in the State has been 33.5 inches, being much less than in eastern Massachusetts.

Some of our greatest rainfalls will run up to 10 inches in two days. These are, no doubt, local, but in one case in June, 1880, this extreme fall was established by evidence in court of many witnesses, and proved to have extended over several hundred square miles area.

D. FITZGERALD, M. Am. Soc. C. E.—In regard to the statements by Prof. Fletcher, I would say that it is impossible to draw inferences as to averages from short periods of rainfall observations, such as, say, twenty years. Owing to great fluctuations in a profile covering as long a period as a century, it makes a great difference when the twenty-year period is taken. I am inclined to the belief that it will take more than a hundred years of observations in the same spot to determine any law as to increase or decrease of the annual fall—at any rate, if that increase or decrease is no more decided in amount than at present appears

As to height above the ground, I have satisfied myself by long experiment that it makes a great difference in the amount collected whether the gauge be placed on the ground or at some distance above it. This fact has already been pretty well established in England. I am now carrying on an experiment with a series of nine gauges and towers, the highest 60 feet above the ground, in connection with a self-recording anemometer, to see if the wind is the cause. Unfortunately, there is hardly any branch of meteorological work in which there are such inaccuracies as in rainfall observations. Here is a great field for missionary work, and one in which I hope this Society will take the initiative. It is desirable to accomplish two objects: 1st, to secure similar instruments, and 2d, to secure uniform methods of observation.

My observation and study have hardly led me to the conclusion that the removal of the forests has any influence on the yearly rainfall, but as it is most probable that their removal affects, in a large degree, the evaporation from the ground, and the distribution of the rainfall after it has been received, it is to be hoped that our influence will be given towards their retention.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXCIII.
(Vol. XIII.—November, 1884.)

DESCRIPTION OF SOME EXPERIMENTS ON THE FLOW OF WATER THROUGH 2½-INCH RUBBER HOSE, AND NOZZLES OF VARIOUS FORMS AND SIZES, MADE ON THE PROVIDENCE, R. I., WATER WORKS. ALSO RESULTS OF INVESTIGATIONS RELATING TO THE HEIGHT OF JETS OF WATER.

By EDMUND B. WESTON, M. Am. Soc. C. E.

READ SEPTEMBER 3D, 1884.

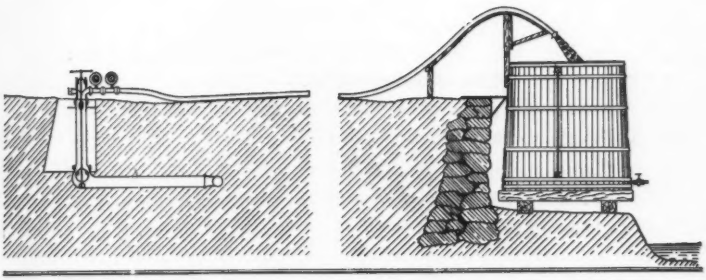
These experiments were made during the year 1877, by the direction of Mr. S. M. Gray, M. Am. Soc. C. E., City Engineer, for the purpose of determining with accuracy the loss of head in ordinary 2½-inch rubber hose, and nozzles of different forms and sizes, such as are generally used by fire departments, as the data at hand was inadequate to cover the varied information that the City Engineer's office was called upon to furnish.

Formulas of different kinds have been determined from the experiments, and Box's formula for the height of jets of water arranged so that it can be used in connection with these formulas.

2½-Inch Rubber Hose.

The supply of water used in making the twenty-four experiments from which a formula for 2½-inch rubber hose has been determined, was taken from a 30-inch main, through a 6-inch pipe about 1 800 feet long.

At the end of this pipe an 8-inch hydrant was located, to the head of which was connected the couplings with the two pressure gauges attached that were employed in determining the head. The general arrangements are shown in the following sketch. From the gauge coup-



lings the attached hose was laid along the ground to a crane arranged to swing over a tank capable of holding 2 100 gallons. Three different lengths of hose were used in making the experiments, viz.: 96.25 feet, 193.25 feet, and 385.02 feet, each length having been thoroughly examined.

The experiments were conducted in the following manner. A short time before each was commenced the water was let into the hose, and the pressure regulated by opening or closing one or more of the valves in the hydrant head. This was done in such a way that contractions or disturbances of any kind did not take place in the outlet that supplied the hose. When all was in readiness word was given, and by the aid of the crane the outlet of the hose was swung over the tank, the time noted with a stop watch, and two observers commenced to read the pressure gauges; after a sufficient time had elapsed, word was again given, the outlet was swung from over the tank, the time noted, and the observers discontinued their readings. The valves in the hydrant head were then

closed, and when the water in the tank had become motionless it was gauged, and the tank emptied preparatory to another experiment.

From the data thus obtained, with the lengths and diameter of the hose, etc., the co-efficients of friction that have been used in the following formulas were determined :

$$v = \sqrt{\frac{2gh}{1. - .0256d^4 + \left(.0087 + \frac{.0504}{\sqrt{v_1}}\right).12288d^4 l}} \qquad (1.)$$

$$v = \sqrt{\frac{h}{.0155463 - .000398d^4 + .0000362962d^4 l}} \qquad (2.)$$

v = velocity of efflux in feet per second.

h = head in feet indicated by pressure guage, more or less the difference in elevation of the outlet.

d = diameter of hose couplings in inches.

l = length of hose in feet from centre of gauge.

v_1 = velocity in 2½-inch hose.

Formula No. 1 is only to be applied to hose between 90 and 100 feet in length, and was especially computed for cases where great accuracy is required. The co-efficient of friction used in its construction is dependent upon the velocity of the water in the hose. A comparison between this co-efficient and the experimental results from which it was derived is shown on diagram No. 1, Part 2, Plate LI ; and a comparison of velocities calculated by this formula, with experimental results, is shown in table No. 2 and on diagram No. 3, Plate LII.

Formula No. 2 can be applied to all lengths of hose, and is a reliable general formula. The co-efficient of friction used in its construction has been considered constant for all velocities. A comparison between this co-efficient and the experimental results from which it was derived, is shown on diagram No. 1, Part 1, Plate LI ; and a comparison of velocities calculated by this formula, with experimental results, is shown in table No. 1 and on diagram No. 2, Plate LII.

It will be seen by the tables and diagrams, that the velocity in the hose ranged during the experiments from 16 to 29 feet per second ; and

that the velocity in the hose of some of the miscellaneous experiments, with which the formula has been compared, ranged as low as 6 feet per second.

As the reliability of pressure gauges may be questioned, attention is called to the fact that two were used in nearly every instance, one as a check upon the other; and by inspecting table No. 1 and diagram No. 2, Plate LII, it will be seen that all of the experiments were made with heads above 40 feet. Therefore, a small error, owing to the inefficiency of the gauges, would only have slightly affected the final results.

For example, take the data of experiments Nos. 23 and 12, table No. 1, their heads being a fair representation of the maximum and minimum heads employed, and assume an error of 1 pound, which corresponds to 2.31 feet of water. After making an allowance for this error, compute with the corrected heads a co-efficient of friction for each case; then with these new co-efficients and the actual heads and lengths of hose, etc., used in the above mentioned experiments, calculate new velocities, and compare them with the experimental velocities given in the table, and the difference will be found to vary with the maximum head only $\frac{8}{10}$ per cent., and with the minimum $2\frac{5}{10}$ per cent.

Ring Nozzles.

The forty-five experiments from which a formula for ring nozzles was determined, are the most unsatisfactory of any that have been considered. They were made with four different sized nozzles (see Plate L), and the velocities obtained ranged from 38 to 95 feet per second.

The head at the base of the nozzle was ascertained by the aid of a pressure gauge.

$$H = h + v_1^2 \, .0155463 \qquad (3.)$$

h = head in feet indicated by gauge.

v_1 = velocity in 2½-inch couplings in feet per second.

H = effective head in feet at base of nozzle.

The quantity of water discharged was measured.

The diameters of the contracted veins were ascertained by measuring the cross-section of the moving streams as they issued from the several orifices. The mean of these measurements was found to correspond to $\frac{8}{10}\frac{6}{0}\frac{4}{0}$ of the diameter of the orifices; consequently the discharge was about $\frac{2}{10}\frac{6}{0}\frac{4}{0}$ less than though the streams had not been contracted, and were issuing from the orifices with the same velocity as the velocity of the contracted veins; while the velocity of the contracted veins was about $\frac{3}{10}\frac{4}{0}$ more than the velocity of the streams in the orifices.

From the experimental data, etc., obtained, the co-efficients of contraction, velocity, and finally that of efflux, were determined that were used in the following formula, which was constructed for general use, and for all sizes of nozzles from ¾ of an inch to 1½ inches in diameter:

$$hf = .001135 \, v^2 \qquad (4.)$$

hf = loss of head in feet owing to resistance.

v = velocity of the contracted vein in feet per second.

A comparison is shown on diagram No. 4, Plate LIII, between this formula, which is indicated by a full black line, and the experiments from which it was derived, which are represented by various dots, etc. On the same diagram it is also compared with formulas computed from individual data obtained from each nozzle, which are indicated by different broken lines. In the construction of this general formula it was taken into consideration, as diagram No. 4 will show, that a very slight variation in the shape of the nozzle would change the co-efficient of resistance quite materially; and the probabilities were, that should another series

of experiments be made with other nozzles of the same pattern, manufactured as near as they generally are for ordinary use, exactly the same results might not be obtained. Therefore this general formula may be considered practicable for all ordinary purposes, and it will greatly facilitate calculation by being constant for all sizes. The difference between this general formula and the formula that represents the maximum and minimum variations from it, which are shown on diagram No. 4 by two of the broken lines, will not materially affect general results, as may be seen by the following example:

Assume a 1-inch nozzle discharging under a head of 138.6 feet, or 60 pounds pressure, and compare the result that will be obtained by the general formula with those results that will be obtained by the maximum and minimum formulas above mentioned, and the quantity discharged by the general formula will be found to vary from either of the others but about $1\frac{5}{10}$ per cent., while the height that a jet will rise will be affected in about the same ratio. The loss of head will be, however,

By the general formula, 9.4 feet,
" " maximum " 12.8 "
" " minimum " 6.1 "

showing a variation of 3.4 feet more and 3.3 feet less.

On diagrams Nos. 6, Plate LIV, and 7, Plate LV, and in table No. 3, where various miscellaneous experiments are compared with the general formula, it will be seen that the ratios of the experimental velocities to the velocities calculated by formula, are not the same as are the ratios of the experimental quantities discharged to the quantities discharged as calculated by formula. This is owing to an individual experimental co-efficient of contraction having been used in each case in determining the experimental velocity, while in the formula a mean co-efficient of contraction was used, as has previously been explained. If, however, the co-efficients of contraction used in determining the experimental velocities had been the same as the one that was used in the formula, their ratios would have been the same as the ratios of the quantities discharged.

Smooth Nozzles.

The thirty-five experiments from which a formula for smooth nozzles was determined, were made with three different sized nozzles (see Plate L), and the velocities obtained ranged from 38 to 92 feet per second.

The head at the base of the nozzles was ascertained by the aid of a pressure gauge.

$$H = h + v_1{}^2 \ .0155463 \qquad (5.)$$

h = head in feet indicated by gauge.

v_1 = velocity in 2½-inch coupling in feet per second.

H = effective head in feet at base of nozzle.

The quantity of water discharged was measured.

From the experimental data, etc., obtained, the co-efficients of velocity and resistance were determined that were used in the following formula, which was constructed for general use, and for all sizes of nozzles from ¾ of an inch to 1½ inches in diameter:

$$hf = .0009639 \ v^2 \qquad (6.)$$

v = velocity of efflux in feet per second.

hf = loss of head in feet owing to resistance.

A comparison is shown on diagram No. 5, Plate LIII, between the formula, which is indicated by a full black line, and the experiments from which it was derived, which are represented by various dots, etc. On the same diagram it is also compared with formulas computed from individual data obtained from each nozzle, which are indicated by different broken lines. In the construction of this general formula, as much care and attention was paid to details as there was upon the one before mentioned for ring nozzles.

The difference between this general formula and the formulas that represent the maximum and minimum variations from it, which are shown on diagram No. 5 by two of the broken lines, will not materially affect general results, as may be seen by the following example:

Assume a 1-inch nozzle discharging under a head of 138.6 feet, or 60 pounds pressure, and compare the result that will be obtained by the general formula with those results that will be obtained by the maximum and minimum formulas above mentioned, and the quantity discharged by the general formula will be found to vary from either of the

others but about 1 per cent., while the height that a jet will rise will be affected in about the same ratio. The loss of head will be, however,

By the general formula, 8.1 feet,
" " maximum " 10.3 "
" " minimum " 6.7 "

showing a variation of 2.2 feet more and 1.4 feet less.

Pressure Gauges.

The pressure gauges used in making the preceding experiments were hydraulic gauges of the best quality; their faces were 7 inches in diameter, and graduated to half pounds, reading from zero to one hundred; they were compared frequently while the experiments were being made with a large test-gauge kept expressly for this purpose.

Efficiency of Nozzles.

It seems to be the opinion among a certain class of people, whose experience with nozzles has been mainly confined to observing in a general way the height of jets of water, as they have noticed them from time to time being played from nozzles of various forms and sizes, that jets will rise to a greater elevation from ring nozzles than they will from smooth nozzles of the same diameter. Experiments, however, prove to the contrary.

The orifice of a ring nozzle, which is in a measure similar to an orifice in a thin plate, causes the stream to contract as it passes through it. Professor Weisbach says upon the subject: "If the velocities of efflux and the widths of the orifices are the same, those streams which are not contracted rise higher than those which are, not only because the former are thicker, but also because the latter, in consequence of their contractions and expansions, oppose less resistance to the penetration of air." On diagram No. 11, Plate LIX, are plotted results of Professor Weisbach's investigations, which show the influence that contraction has upon the height of jets.

The opinion of the superiority of ring nozzles may have been formed owing to unjust comparison. For instance, assume that vertical streams are being played under 157.7 feet head through 200 feet of hose to which nozzles are attached; from a 1-inch smooth nozzle a jet will rise about 92 feet, while the head due to the velocity of the stream will be 105 feet,

and the discharge 3.35 gallons per second; and from a 1-inch ring nozzle a jet will rise about 98.5 feet, while the head due to the velocity of the contracted vein will be 119.6 feet, and the discharge 2.67 gallons per second; showing a gain in favor of the ring nozzle of 6.5 feet in the height of jet, and 14.6 feet in the head due to the velocity, while there is a decrease in the discharge of $\frac{68}{100}$ gallons per second, or 20 per cent.

These differences can be easily accounted for, as a stream that issues from a ring nozzle is contracted to $\frac{864}{1000}$ of the diameter of the orifice, as has been explained in the preceding pages; consequently the discharge is less than it would be from a stream issuing without contraction from the orifice of a smooth nozzle of the same diameter, and the loss of head in the hose is not as great. In the preceding case the head under which the nozzles were discharging, was for the ring 128.3 feet, and for the smooth 111.4 feet, showing about 17 feet head in favor of the ring, which caused the jet to rise higher though the discharge was less. If the head on the nozzles had not been unequally reduced, however, by loss of head in the hose, and in both instances had been the same, different results would have been obtained, as a jet of large diameter will rise higher than a jet of small diameter under the same head. For instance, under a head of 115 feet a jet will rise from a 1-inch smooth nozzle about 94.3 feet, while the head due to the velocity will be 108.3 feet, and the discharge 3.4 gallons per second; and from a ring nozzle of the same diameter, and under the same head, a jet will rise about 91 feet, while the head due to the velocity of the contracted vein will be 107.2 feet, and the discharge 2.53 gallons per second.

Jets of Water.

Investigation demonstrates that Box's formula for the height of jets, as published in his "Practical Hydraulics," compares as favorably with obtainable experimental results as can be reasonably expected of a formula so general in its application.

A comparison of this formula and the experiments from which it was determined with others from the following authorities, that have been added for the purpose of substantiation, are shown on diagrams Nos. 9, Plate LVII, and 10, Plate LVIII, and in tables Nos. 5 and 6.

Eleven experiments from a paper published in the *Engineering News*, by S. Van Cleve, Superintendent of the Des Moines Water Works. The pressure gauge from which the head was obtained under which these experiments were made, was located upon a line of 2½-inch hose 50 feet distant from the nozzle, and the head at the nozzle was determined by calculating the loss of head in the 50 feet of hose by the formula mentioned in the preceding pages, and subtracting it from the head indicated by the gauge, after the head due to the velocity in the coupling of the hose had been added.

Twelve experiments where the greatest elevation of the jets was apparently considered, from a paper published in the *Engineering News*, by J. F. Flagg, C. E. The pressure gauge from which the head was determined under which these experiments were made, was attached probably to a 6 or 8-inch pipe a short distance from the orifice, and the head on the jet was considered the same as indicated by this gauge.

Seven experiments from D'Aubuisson's Hydraulics, made by Mariotte and Bossut.

On diagram No. 11, Plate LIX, Box's formula is compared with several by Professor Weisbach; the head due to the velocity, which is a term of the latter, has been increased in order to make the comparison 5.3 per cent., which corresponds to a mean co-efficient of resistance for nozzles and thin plates by the same author.

Box, in his "Practical Hydraulics," says in reference to jets:

"There are very few reliable experiments on this subject, and the laws indicated by those we have are very intricate. The best experiments we have are given in Table," "and from them we find that h' increases very nearly in the ratio of the square of the head, so that if we draw to scale the successive heights found by experiment, as in Figure," "we obtain a curve which approximates to a parabola." "Experi-

ment also shows that the head being constant h' varies nearly in inverse ratio to the diameter of the jet." "Thus we have the elements for calculating approximately the loss of head for any particular case, not perfectly agreeing, perhaps, with the true law, but the best approximation we can obtain; this is a subject on which more experimental information is very desirable."

$$h' = \frac{H^2}{d} \times .0125,$$

in which

H = head on jet in feet,

h' = the difference between the height of head and height of jet,

d = diameter of jet in eighths of an inch.

"It is a result of this rule that each particular size of jet attains its maximum height with a certain head, and that if the head be increased beyond that point the height of jet is not increased thereby, but is actually diminished," as shown on diagram No. 10, Plate LVII.

The data obtainable indicates that in making the experiments upon which Box's formula was based, probably only the head on the nozzles or orifices, and the height and diameter of the jets, were measured. It is, therefore, reasonable to suppose that, as the head on the nozzle and not the head due to the velocity of the jet is used in the formula, the resistance to flow considered in its construction is not that due to any particular form of nozzle. The slight effect, however, which the difference in the resistances to flow of various kinds of nozzles will have upon the height of jets, may be seen by the following comparison:

Assume that Box's formula is based upon the form of smooth nozzle shown on Plate L, and that a jet is being played from a 1-inch nozzle of this form under 100 feet head. The height that a jet will rise by the formula from this nozzle under these conditions, and the heights that jets will rise by the formula under the same head, from other nozzles or orifices of the same size having different resistances to flow, after allowance has been made for them in the formula, are as follows:

Kind of Nozzles or Orifices, and Authority.	Height of Jets.	Difference.
Smooth. See Plate L.	84.0	.....
Ring. " " "	82.8	— 1.2
Smooth. By Weisbach	84.5	+ .5
Thin plate. " "	84.0	0.0
Smooth. " Box	80.6	— 3.4

Formulas.

The following formulas on the flow of water through 2½-inch rubber hose and smooth and ring nozzles, such as are ordinarily used by fire departments, have been arranged from the general formula presented in the preceding pages, and are intended to be used in connection with all lengths of hose over 40 feet, and for nozzles ranging in size from ¾ of an inch to 1½ inches inclusive. The head in all cases has been considered as that which would be indicated by a pressure gauge attached to a 2½-inch coupling connected with a line of hose, and is equal to what the actual head would be at the same point, less the head due to the velocity in the coupling.

Formulas for 2½-inch rubber hose with smooth nozzles attached:

$$v = \sqrt{\frac{h}{.0165102 - .000398d^4 + .0000362962d^4 l}} \tag{7.}$$

$$G = .0408d^2 v \tag{8.}$$

$$h = (.0165102 - .000398d^4 + .0000362962d^4 l)v^2 \tag{9.}$$

$$\frac{v^2}{2g} = \frac{h}{1.062 - .0256d^4 + .00233472d^4 l} \tag{10.}$$

$$H = .01651v^2 \tag{11.}$$

$$h_J = .01651v^2 - \frac{.000000426v^4}{d} \tag{12.}$$

v = velocity of efflux in feet per second.

h = head in feet indicated by pressure gauge, more or less the difference in elevation of the orifice of the nozzle.

d = diameter of nozzle in inches.

l = length of hose in feet from the centre of the pressure gauge to the base of the nozzle.

G = gallons discharged per second.

$\frac{v^2}{2g}$ = head in feet due to velocity of efflux.

H = effective head in feet at the nozzle.

h_J = height in feet that a jet will rise above the orifice in still air.

Formulas for 2½-inch rubber hose with ring nozzles attached:

$$v = \sqrt{\frac{h}{.0166812 - .00022178d^4 + .0000202264d^4 l}} \tag{13.}$$

$$G = .030457d^2 v \tag{14.}$$

$$h = (.0166812 - .00022178d^4 + .0000202264d^4 l)v^2 \tag{15.}$$

$$\frac{v^2}{2g} = \frac{h}{1.073 - .0142658d^4 + .00130104d^4 l} \tag{16.}$$

$$H = .01668v^2 \tag{17.}$$

$$h_J = .01668v^2 - \frac{.000000503v^4}{d} \tag{18.}$$

v = velocity of efflux of the contracted vein, in feet per second.

h = head in feet indicated by pressure gauge, more or less the difference in elevation of the orifice of the nozzle.

d = diameter of nozzle in inches.

l = length of hose in feet from the centre of the pressure gauge to the base of the nozzle.

G = gallons discharged per second.

$\frac{v^2}{2g}$ = head in feet due to velocity of efflux.

H = effective head in feet at base of nozzle.

h_J = height in feet that a jet will rise above the orifice in still air.

$$v = \frac{G}{(d \times .864)^2 \times .785398 \times .051946}$$

The following examples will show the manner of applying formulas Nos. 7, 8, 12, 13, 14, and 18:

Example No. 1.

Assume that a stream of water is being discharged vertically through a smooth nozzle attached to a line of hose, and the orifice of the nozzle is 4 feet above the elevation of a gauge, connected to the hose near the hydrant, and from which the head is obtained.

Length of hose from centre of gauge to base of nozzle, 200 feet. Diameter of nozzle, 1 inch.

Head indicated by pressure gauge, 161.7 feet less 4 feet = 157.7 feet = h.

Question. What will be the velocity of efflux per second ?

Answer. 82.14 feet.

Question. What will be the discharge of water in gallons per second ?

Answer. 3.35 gallons.

Question. How high will the jet of water rise ?

Answer. 92.01 feet.

Example No. 2.

Assume that a stream of water is being discharged vertically through a ring nozzle attached to a line of hose, and the orifice of the nozzle is 4 feet above the elevation of a gauge, connected to the hose near the hydrant, and from which the head is obtained.

Length of hose from centre of gauge to base of nozzle, 200 feet. Diameter of nozzle, 1 inch.

Head indicated by pressure gauge, 161.7 feet less 4 feet=157.7 feet = h.

Question. What will be the velocity of efflux per second ?

Answer. 87.70 feet.

Question. What will be the discharge of water in gallons per second ?

Answer. 2.67 gallons.

Question. How high will the jet of water rise ?

Answer. 98.53 feet.

TABLE No. 1.

Corresponding to Diagram No. 2, and a Portion of No. 8.

Velocity of efflux through coupling of 2½" rubber hose; comparison of formula with experiments.

$$v = \sqrt{\frac{h}{.0155463 - .000398d^4 + .0000362962d^4 l}}$$

h = head in feet indicated by pressure gauge *

l = length of hose in feet from centre of gauge.

d = diameter of coupling in inches.

No. of Exp.	Head.	Length.	Diam. of Coupling.	Velocity by Calculation.	Velocity by experiment.	Ratio, Calculation to Experiment.		Diff. % from Experiment.		Remarks
						−	+	−	+	
1	111.64	96.25	2½"	34.30	35.52	.966	.....	3.4	.....	Experiments used in determining the above formula.
2	111.91	"	"	34.34	35.09	.979	.....	2.1	.....	
3	112.76	"	"	34.47	35.07	.983	.....	1.7	.....	
4	113.03	"	"	34.51	34.64	.996	.....	0.4	.....	
5	82.81	"	"	29.54	29.76	.993	.....	0.7	.....	
6	82.46	"	"	29.48	29.80	.989	.....	1.1	.....	
7	82.26	"	"	29.44	30.10	.978	.....	2.2	.....	
8	59.10	"	"	24.96	24.63	.....	1.013	.....	1.3	
9	59.38	"	"	25.02	24.52	.....	1.020	.....	2.0	
10	60.21	"	"	25.19	23.95	.....	1.052	.....	5.2	
11	43.56	"	"	21.43	20.01	.....	1.071	.....	7.1	
12	43.74	"	"	21.47	20.77	.....	1.034	.....	3.4	
13	44.51	"	"	21.66	20.67	.....	1.048	.....	4.8	
14	128.02	193.25	"	26.30	26.02	.....	1.011	.....	1.1	
15	127.59	"	"	26.25	26.52	.990	.....	1.0	.....	
16	126.56	"	"	26.15	26.48	.988	.....	1.2	.....	
17	126.44	"	"	26.13	26.47	.987	.....	1.3	.....	
18	103.22	"	"	23.61	23.88	.989	.....	1.1	.....	
19	103.39	"	"	23.63	23.83	.992	.....	0.8	.....	
20	102.90	"	"	23.58	23.86	.988	.....	1.2	.....	
21	135.24	385.02	"	19.29	20.12	.959	.....	4.1	.....	
22	136.07	"	"	19.35	19.58	.988	.....	1.2	.....	
23	136.03	"	"	19.34	19.63	.985	.....	1.5	.....	
24	136.26	"	"	19.36	19.53	.991	.....	0.9	.....	
25	138.06	600.00	"	15.65	16.76	.934	.....	6.6	.....	Miscellaneous experiments.
26	139.14	"	"	15.71	16.74	.938	.....	6.2	.....	
27	139.12	"	"	15.71	16.67	.942	.....	5.8	.....	
28	139 61	"	"	15.74	16.67	.944	.....	5.6	.....	
29	141.87	981.50	"	12.43	13.25	.938	.....	6.2	.....	
30	140.92	"	"	12.39	13.19	.939	.....	6.1	.....	

* More or less the difference in elevation of the orifice of the nozzle.

TABLE No. 2.

Corresponding to Diagram No. 3.

Velocity of efflux through coupling of 2¼-inch hose; comparison of formula with experiments from which it was derived.

$$v = \sqrt{\frac{2gh}{1 - .0256d^4 + \left(.0087 + \frac{.0504}{\sqrt{v_1}}\right).12288d^4}}$$

l = length of hose in feet from centre of gauge.

h = head in feet indicated by pressure gauge.*

d = diameter of coupling in inches.

v_1 = velocity in 2¼-inch hose.

$2g = 64.324$.

No. of Exp.	Head.	Length.	Diam. of Coupling.	Velocity by		Ratio of Calculation to Experiment.		Diff. % from Experiment.		Remarks.
				Calculation.	Experiment.	—	+	—	+	
1	111.64	96.25	2¼″	35.09	35.52	.988	.....	1.2	.....	
2	111.91	96.25	"	35.09	35.09	.....	.....	.....	.....	
3	112.76	96.25	"	35.22	35.07	.....	1.004	.....	0.4	
4	113.03	96.25	"	35.20	34.64	.....	1.016	.....	1.6	
5	82.81	96.25	"	29.57	29.76	.994	.....	0.6	.....	
6	82.46	96.25	"	29.51	29.80	.990	.....	1.0	.....	
7	82.26	96.25	"	29.51	30.10	.980	.....	2.0	.....	
8	59.10	96.25	"	24.37	24.63	.989	.....	1.1	.....	
9	59.38	96.25	"	24.41	24.52	.996	.....	0.4	.....	
10	60.21	96.25	"	24.50	23.95	.....	1.023	.....	2.3	
11	43.56	96.25	"	20.34	20.01	.....	1.016	.....	1.6	
12	43.74	96.25	"	20.48	20.77	.986	.....	1.4	.....	
13	44.51	96.25	"	20.65	20.67	.999	.....	0.1	....	

More or less the difference in elevation of the orifice of the nozzle.

TABLE No. 3.

Corresponding to Diagrams Nos. 6 and 7.

Velocity of efflux and discharge through ring nozzles attached to 2¼-inch rubber hose; comparison of formulas with miscellaneous experiments.

$$v = \sqrt{\frac{h}{.0166812 - .00022178d^4 + .0000202264d^4 l}}$$

$$Q = .00407153d^2 \sqrt{\frac{h}{.0166812 - .00022178d^4 + .0000202264d^4 l}}$$

v = velocity of efflux of the contracted vein in feet per second.
Q = discharge in cubic feet per second.
h = head in feet indicated by pressure gauge.*
l = length in feet of hose from centre of gauge.
d = diameter of nozzle in inches.
Kind of nozzle, brass ring.

No. of Exp.	Head.	Length.	Diameter of Nozzle. Nominal.	Diameter of Nozzle. Actual.	Velocity by Calculation.	Velocity by Experiment.	Ratio of Calculation to Experiment. −	Ratio of Calculation to Experiment. +	Diff. % from Experiment. −	Diff. % from Experiment. +	Discharge by Calculation.	Discharge by Experiment.	Ratio of Calculation to Experiment. −	Ratio of Calculation to Experiment. +	Diff. % from Experiment. −	Diff. % from Experiment. +	Remarks.
34	145.91	96.25	7/8"	.88"	90.75	89.95	.....	1.009	.....	0.9	.2861	.2687	.....	1.065	.....	6.5	For explanation of difference of ratios between velocities and cubic feet per second, see the text.
35	145.24	"	"	"	90.55	89.85	.....	1.008	.....	0.8	.2855	.2684	.....	1.064	.....	6.4	
36	140.82	"	"	"	89.16	88.47	.....	1.008	.....	0.8	.2811	.2643	.....	1.064	.....	6.4	
37	132.93	"	"	"	86.62	86.00	.....	1.007	.....	0.7	.2731	.2569	.....	1.063	.....	6.3	
38	125.36	"	"	"	84.12	83.28	.....	1.010	.....	1.0	.2652	.2488	.....	1.066	.....	6.6	
138	156.42	97.60	"	"	93.92	94.80	.991	.....	0.9	.....	.2961	.2832	.....	1.046	.....	4.6	
139	156.39	"	"	"	93.91	95.07	.988	.....	1.2	.....	.2961	.2840	.....	1.043	.....	4.3	
46	145.77	193.25	"	"	87.84	90.72	.968	.....	3.2	.....	.2770	.2710	.....	1.022	.....	2.2	
56	161.37	101.00	7/8"	.89"	95.15	94.99	.....	1.002	.....	0.2	.3069	.3032	.....	1.012	.....	1.2	
57	154.86	"	"	"	93.21	94.12	.990	.....	1.0	.....	.3006	.3004	.....	1.001	.....	0.1	
60	120.42	"	"	"	82.20	78.75	.....	1.044	.....	4.4	.2651	.2514	.....	1.055	.....	5.5	
64	68.95	"	"	"	62.20	61.87	.....	1.005	.....	0.5	.2006	.1975	.....	1.016	.....	1.6	
70	68.05	"	"	"	61.79	61.74	.....	1.001	.....	0.1	.1993	.1971	.....	1.011	.....	1.1	
42	144.00	193.25	1"	1.01"	83.78	83.54	.....	1.003	.....	0.3	.3479	.3526	.987	.....	1.3	.....	
43	143.10	"	1"	1.01"	83.51	82.21	.....	1.016	.....	1.6	.3469	.3470	.000	.....	0.0	.....	
45	142.81	"	1"	1.01"	83.43	82.92	.....	1.006	.....	0.6	.3465	.3500	.990	.....	1.0	.....	
55	143.13	978.00	1"	1.01"	62.17	64.58	.963	.....	3.7	.....	.2582	.2726	.947	.....	5.3	.....	

* More or less the difference in elevation of the orifice of the nozzle.

TABLE No. 4.

Corresponding to Diagram No. 8.

Velocity of efflux through smooth nozzles attached to 2½-inch rubber hose; comparison of formula with miscellaneous experiments.

$$v = \sqrt{\frac{h}{.0165102 - .000398d^4 + .000362962d^4 l}}$$

v = velocity of efflux in feet per second.
h = head in feet indicated by pressure gauge.*
l = length of hose in feet from centre of gauge.
d = diameter of nozzle in inches.

No. of Exp.	Head.	Length.	Diameter of Nozzle. Nominal.	Diameter of Nozzle. Actual.	Velocity by Calculation.	Velocity by Experiment.	Ratio of Calculation to Experiment —	Ratio of Calculation to Experiment +	Diff. % from Experiment. —	Diff. % from Experiment. +	Kind of Nozzle.	Remarks.
74	136.41	101.00	$\frac{7}{8}$"	.89"	85.73	88.40	.970	....	3.0	....	Brass smooth.	
77	125.30	"	"	"	82.16	84.16	.976	....	2.4	....	" "	
83	69.53	"	"	"	61.21	62.31	.982	....	1.8	....	" "	Calculated from a head obtained during experiment No. 146, from a gauge graduated to each 5 pounds, located 175.50 feet from the nozzle.
146	140.15	827.50	"	.875"	64.31	65.95	.975	....	2.5	....	" "	
146[1]	78.87	175.50	"	"	62.06	"	.941	....	5.9	....	" "	
115	137.08	97.60	1"	1.025"	82.83	84.29	.983	....	1.7	....	" "	
116	135.20	"	"	"	82.26	83.88	.981	....	1.9	....	" "	
31	122.77	96.25	1½"	1.5"	61.77	64.46	.958	....	4.2	....	Plain rubber.	Nominal diameter considered.
32	123.50	"	"	"	61.95	64.43	.962	....	3.8	....	" "	
33	123.78	"	"	"	62.02	65.12	.952	....	4.8	....	" "	
47	137.16	385.02	"	"	40.11	42.55	.943	....	5.7	....	" "	
48	136.95	"	"	"	40.08	42.61	.941	....	5.9	....	" "	
51	140.76	600.00	"	"	33.59	35.46	.947	....	5.3	....	" "	
52	138.22	"	"	"	33.29	35.51	.937	....	6.3	....	" "	
53	141.71	981.50	"	"	26.97	28.79	.937	....	6.3	....	" "	
54	142.26	"	"	"	27.02	28.73	.940	....	6.0	....	" "	
147	136.84	484.00	"	"	36.37	36.35	....	1.001	....	0.1	" "	Calculated from a head obtained during experiment No. 147, from a gauge graduated to each 5 pounds, located 150.60 feet from the nozzle.
147[1]	65.91	150.60	"	"	37.77	"	....	1.039	....	3.9	" "	
148	128.91	747.80	"	"	29.13	29.58	.985	....	1.5	....	" "	
148[1]	52.46	182.20	"	"	31.76	"	....	1.074	....	7.4	" "	Ditto from experiment No. 148, gauge located 182.20 feet from the nozzle.
40	127.11	193.25	$1\frac{13}{16}$"	1.6875"	42.56	46.11	.923	....	7.7	....	Brass smooth.	
49	139.77	600.00	"	"	27.13	29.28	.927	....	7.3	....	" "	

* More or less the difference in elevation of the orifice of the nozzle.

TABLE No. 5.

Corresponding to portions of Diagrams Nos. 9 and 10.

Box's formula for the height of jets, compared with experiments obtained from various authorities:

$$\text{Height of jet in feet} = H - \frac{H^2}{d}\ .0125.$$

Manner of application to the general formula for 2½-inch hose, etc., derived from experiments made on the Providence Water Works:

For smooth nozzles, $H = .01651v^2$

For ring nozzles, $H = .01668v^2$

H = head on jet in feet.
d = diameter of jet in eighths of an inch.
v = velocity of efflux in feet per second.

Diameter of Jet in Inches.	Head on Jet in Feet.	Height of Jet in Feet.		Error in Feet.	Loss of Height by Jet in Feet.		
		Experiment.	Calculated.		Experiment.	Calculated.	
1"	105.3	91.8	87.5	— 4.3	13.5	17.8	Experiments from a paper published in the *Engineering News*, by J. F. Flagg, C. E. Section of orifice is shown by cut below.
"	65.0	58.8	58.5	— .3	6.2	6.5	
"	17.7	13.8	17.5	+ 3.7	3.9	.2	
"	105.5	90.7	87.5	— 3.2	14.8	18.0	
"	92.9	81.7	79.	— 2.7	11.2	13.9	
"	82.8	74.6	72.	— 2.6	8.2	10.8	
"	73.0	66.6	65.	— 1.6	6.4	8.0	
"	61.	57.9	55.5	— 2.4	3.1	5.5	
"	50.3	47.0	46.5	— .5	3.3	3.8	
"	42.	39.4	39.5	+ .1	2.6	2.5	
"	33.9	32.2	32.0	— .2	1.7	1.9	
"	21.2	20.2	20.5	+ .3	1.0	.7	
"	223.	138.	145.5	+ 7.5	85.	77.5	Experiments from a paper published in the *Engineering News*, by S. Van Cleve, Supt. of the Des Moines Water Works.
"	175.	117.	127.	+ 10.	58.	48.	
"	175.	139.	127.	— 12.	36.	48.	
"	181.	127.	129.5	+ 2.5	54.	51.5	
"	202.	142.	138.	— 4.	60.	64.	
"	202.	135.	138.	+ 3.	67.	64.	
"	127.	95.	101.5	+ 6.5	32.	25.5	
"	149.	113.	114.	+ 1.0	36.	35.	
"	132.	112.	104.5	— 7.5	20.	27.5	
"	138.	118.	108.	— 10.	20.	30.	
"	170.	107.	124.5	+ 17.5	63.	45.5	
$\frac{13}{100}$"	37.7	34.1	33.	— 1.1	3.6	4.7	Mariotte.
"	37.2	33.8	32.5	— 1.3	3.4	4.7	"
"	27.8	25.8	25.5	— .3	2.0	2.3	"
"	26.	24.3	24.	— .3	1.7	2.0	"
"	13.2	12.8	12.7	— .1	.4	.5	"
"	5.9	5.7	5.8	+ .1	.2	.1	"
$\frac{71}{100}$"	11.7	11.2	11.4	+ .2	.5	.3	Bossut.

Experiments from D'Aubuisson's Hydraulics.

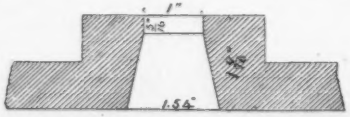


TABLE No. 6.

Corresponding to portions of Diagrams Nos. 9 and 10.

Box's formula for the height of jets, compared with experiments obtained from various authorities:

$$\text{Height of jet in feet} = H - \frac{H2}{d}.0125$$

Manner of application to the general formula for 2½-inch hose, etc., derived from experiments made on the Providence Water Works:

For smooth nozzles, $H = .01651\ v^2$

For ring nozzles, $H = .01668\ v^2$

H = head on jet in feet.
d = diameter of jet in eighths of an inch.
v = velocity of efflux in feet per second.

Diam. of Jet in Inches.	Head on the Jet in Feet.	Height of Jet in Feet.		Error in Feet.	Loss of Height by Jet in Feet.		
		Experiment.	Calculated.		Experiment.	Calculated.	
1⅛"	64.	61.	60.1	— 0.9	3.0	3.9	Witley Court.
"	92.	84.	83.86	— 0.14	8.0	8.14	" "
"	115	103.	102.3	— 0.7	12.	12.7	" "
1"	445.	109.	136.0	+27.0	336.	309.	Torquay.
¾"	46.	43.	41.2	— 1.8	3.	4.8	Witley Court.
"	69.	62.	59.	— 3.0	7.	10.0	" "
"	92.	77.	74.4	— 2.6	15.	17.6	" "
"	115.	93.	87.5	— 5.5	22.	27.5	" "
"	141.	98.	99.6	+ 1.6	43.	41.4	" "
"	162.	106.	107.3	+ 1.3	56.	54.7	" "
⅝"	15.	14.25	14.44	+ 0.19	0.75	0.56	Weisbach.
"	30.	27.81	27.75	— 0.06	2.19	2.25	"
"	45.	39.42	39.94	+ 0.52	5.58	5.06	"
"	60.	48.36	51.00	+ 2.64	11.64	9.00	"
½"	15.	14.04	14.06	+ 0.02	0.96	0.94	"
"	30.	26.44	26.25	— 0.19	3.56	3.75	"
"	45.	36.18	36 56	+ 0.38	8.82	8.44	"
"	60.	42.96	45.00	+ 2.04	17.04	15.00	"
"	32.	27.	27.7	+ 0.7	5.	4.3	Witley Court.
"	46.	36.	37.2	+ 1.2	10.	8.8	" "
"	95.	55.	57.4	+ 2.4	40.	37.6	" "
"	118.	63.	60.	— 3.0	55.	58.0	" "

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TRANSACTIONS.

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CCXCIV.
(Vol. XIII.—November, 1884.)

MANAGEMENT OF FORCES ENGAGED IN RAILWAY TRACK REPAIRS.

By BENJAMIN REECE, M. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION, JUNE 13TH, 1884.

The maintenance of road-bed and way depends upon a multiplicity of details, proper attention to the performance of which rests so largely upon the distribution, training and management of the track forces, that I have determined to make this topic the subject of a paper, trusting it may lead to such an interchange of views as will prove advantageous to those engaged in this very important branch of railroad engineering.

We will presuppose that the track work is supervised by an efficient corps of road masters, and indeed the success of any plan will depend upon the wisdom and good judgment displayed by the engineer in the selection of these important aids, who put into execution the methods and plans adopted. The selection of road masters is a subject to which I have given considerable thought, and after much painstaking observation and experience I am led, as a rule, to select energetic young men, possessed of executive ability and a mechanical turn of mind,

in preference to men who have had many years' experience as section men or foremen. I am aware that, in taking this stand, I oppose generally accepted opinions and well-established practice, for which reason I was slow to take the position now assumed, and to make my own office the stepping-stone to a track position upon the division of railway in my charge. The advantages of this system are, first, that it enables one to keep the apprentice under observation until his capacity is assured, and he becomes familiar with the system of accounts and with all reports pertaining to the department. His general business training is better, and he is better prepared to deal with the public; while it is in one's own hands to instruct him in the details of track repairs, besides his deriving all the advantages of frequent association with the experienced track masters of the division. Of course, there are exceptions to the rule, and men educated from the ranks are sometimes found qualified to make good track masters. When opportunity presents, I am only too glad to recognize this fact by such promotion as the merit of these men deserves, for I know full well the good moral effect following such promotions.

It is true many of our best track masters were originally section foremen, but they received their appointments at a time when the requirements for a track master were scarcely higher than those demanded for a section master now, and they may be said to have grown and developed with the growth and development of railroads themselves, the incompetents having been gradually weeded out as the standard of competency was raised. The difficulty I find with trained track men, as track masters, is their constant tendency to work directly with the men. The training of years in working men directly seems to have incapacitated them for the working of men through the agency of others. They are too often with the work train and spend too much time with this gang, then with that. If a section shows signs of poor judgment or neglect, that impatience, born of their own skill and competency, leads them to seek the remedy by too constant a personal direction, and, while the track is made better, the men in charge are not improved, so the advantage is necessarily short-lived. They seem unable to surround themselves with the proper safeguards and checks which would enable them to detect dereliction in their absence. They govern by special orders, which weaken the individuality and independence of the men, rather than by general rules calculated to develop the men into observ-

ing, thinking and acting entities. They do not make sufficient use of pen and ink, but depend upon their presence and personal direction for the correction of every evil, and thus, while the poorer sections are improved, the general tone of the division frequently runs down. I am not here speaking of men of long and tried experience, but of new appointments. I have here recounted my experience, and I would like to hear from others.

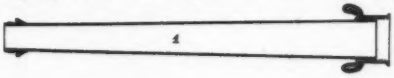
A proper length for sections is a matter of great importance, and so much depends upon a judicious determination of the length of track sections, both as regards the efficient and economic maintenance of roadway and track, that I hope to hear the fullest and freest discussion upon the subject, that all may learn and profit by the judgment and experience of others.

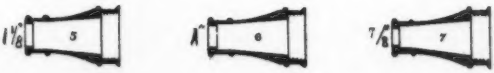
For the purpose of dividing a line of railway into track sections, I assume that the same condition of rails, ballast, ties, surface, drainage, etc., prevails throughout—a state of affairs rarely if ever existing. For the purpose of determining the proper length of sections, I should take no heed of any difference in the conditions named, which are all subject to constant and radical changes, but taking cognizance of the added work of freight-yards or portions of the road, the physical conditions of which are such as to permanently require more labor, I should divide the division into sections of such length that, when in good condition, a minimum summer force will be large enough to perform all work on the sections, including the handling of frogs, timbers, rails and the lining of track, without outside aid. But perhaps I cannot better explain my views than by describing the plan which, with the approval of Mr. L. H. Clarke, Chief Engineer, was introduced on the Michigan Southern Division of the Lake Shore and Michigan Southern Railway.

I have taken five men and a foreman as the minimum summer force to be worked on the track sections of the main lines, and for that number of men the sections are made from six and a half to seven miles in length, with an average of about one mile and a half of passing and station side tracks. The forces in excess of five men and a foreman allowed for the summer's work are not equally distributed over the sections, but are distributed by the road master according to the wants of each section, and by carefully watching the condition of the track, and with a knowledge of the work to be done on each section, the engineer

Nozzles,
and a sample of the hose and couplings
that were used in making the experiments.

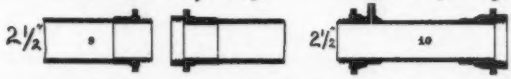
Hose-pipe and adjustible nozzles.





Hose-pipe and fixed nozzle.

Hose and couplings. *Gauge coupling.*



Scale of nos. 1. 8. 9. and 10. 1/12 size.
. . . 2. 3. 4. 5. 6. and 7. 1/8 .

Diagram No. 1.

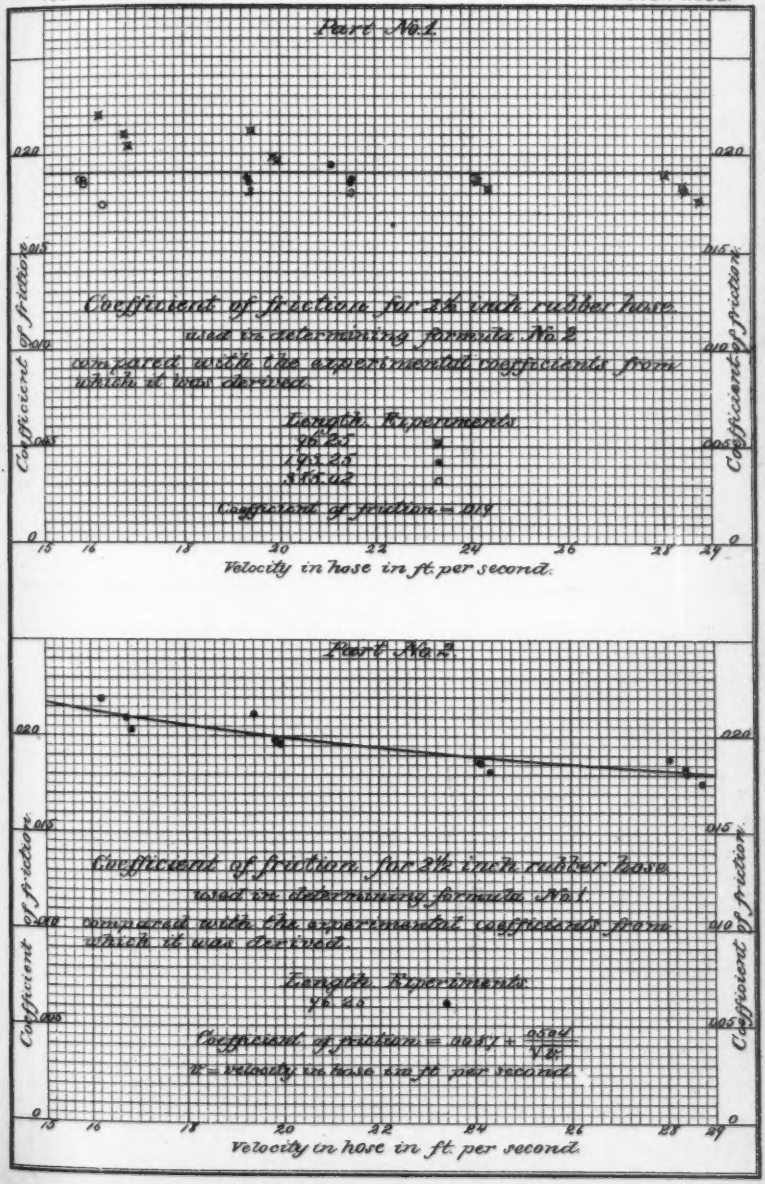

Part No. 1.
Coefficient of friction for 2½ inch rubber hose.
used in determining formula No. 2.
compared with the experimental coefficients from
which it was derived.
Length. Experiments.
96.25
193.25
385.02
Coefficient of friction = .019
Coefficient of friction
Velocity in hose in ft. per second.
Part No. 2.
Coefficient of friction for 2½ inch rubber hose.
used in determining formula No. 1.
compared with the experimental coefficients from
which it was derived.
Length. Experiments.
96.25
Coefficient of friction = .0217 + .0504/√v
v = velocity in hose in ft. per second.
Coefficient of friction
Velocity in hose in ft. per second.

Diagram No 2.

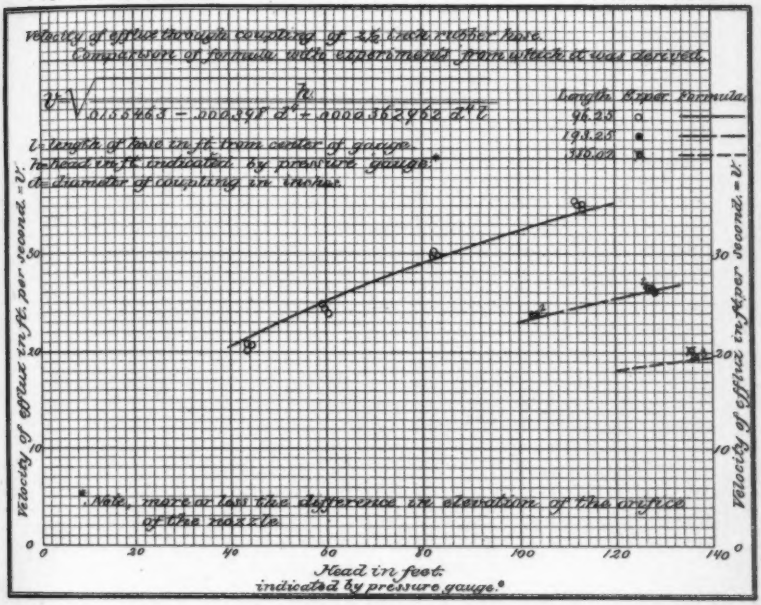


Diagram No. 3.

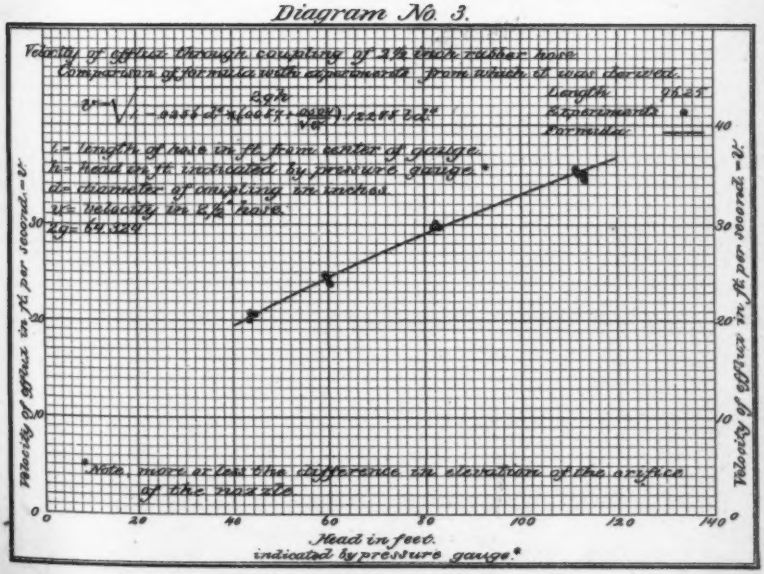


Diagram No. 4.

Loss of head in Ring Nozzles.
Comparison of formulae with experiments.

$h_f = w \frac{v^2}{2g}$

Diameter in inches Nom.	Diameter in inches Actual	Pipe.	Experiment.	Formulae.	w	a	ϕ
7/8	.88	No.8	●	—·—	.080	.707	.962
7/8	.89	No.1	◆	·····	.102	.740	.958
1"	1.01	.1	○	— —	.046	.759	.978
1 1/8	1.145	.1	●	— —	.064	.781	.970
For all sizes.				———	.073	.746	.966

w = coefficient of resistance.

a = coefficient of contraction.

ϕ = coefficient of velocity.

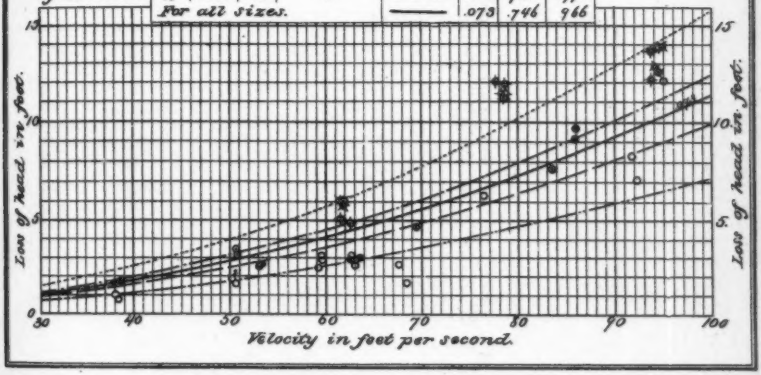


Diagram No. 5.

Loss of head in Smooth Nozzles.
Comparison of formulae with experiments.

$h_f = w \frac{v^2}{2g}$

Diameter in inches Nom.	Diameter in inches Actual	Pipe.	Experiment.	Formulae.	w	ϕ
7/8	.89	No.1	◆	·····	.054	.974
1"	1.025	.1	○	— —	.050	.963
1 1/8	1.14	.1	●	— —	.061	.975
For all sizes.				———	.062	.971

w = coefficient of resistance.

ϕ = coefficient of velocity.

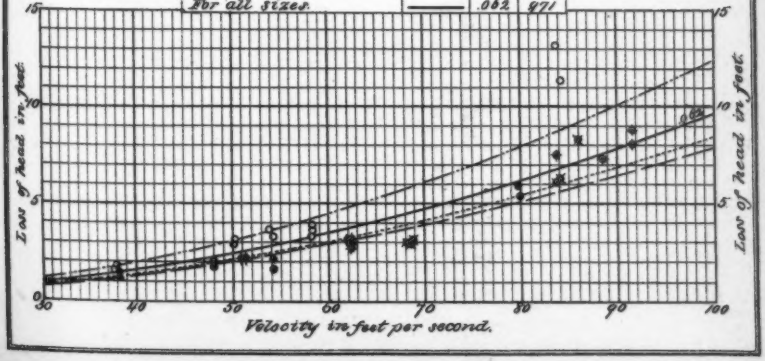


Diagram No. 6.

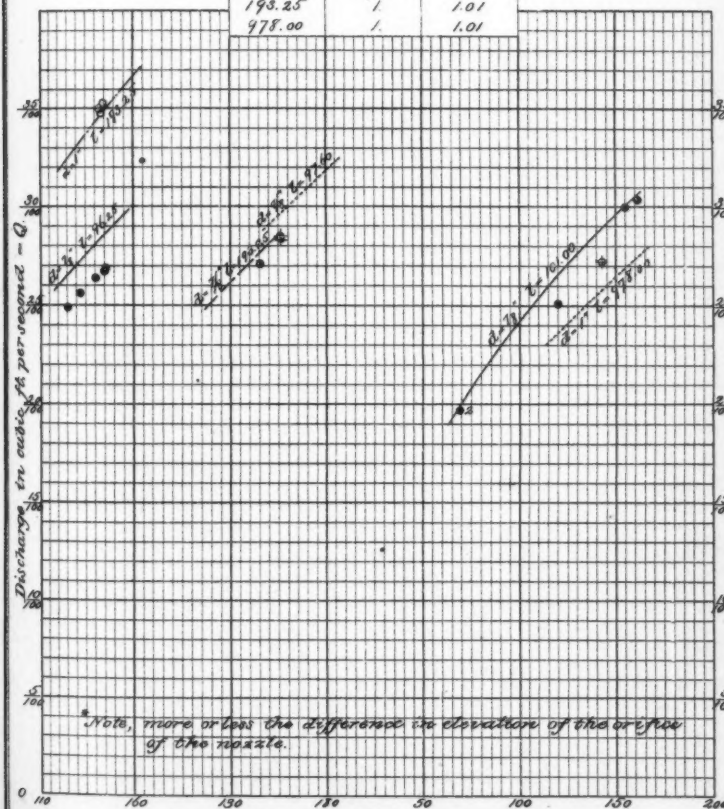
Discharge through ring nozzles attached to 2½ inch rubber hose.

Comparison of formula with miscellaneous experiments.

$$Q = .00407158\, d^2 \sqrt{\frac{h}{.01665/12 - .00022178\, d^4 + .0000202264\, d^4 l}}$$

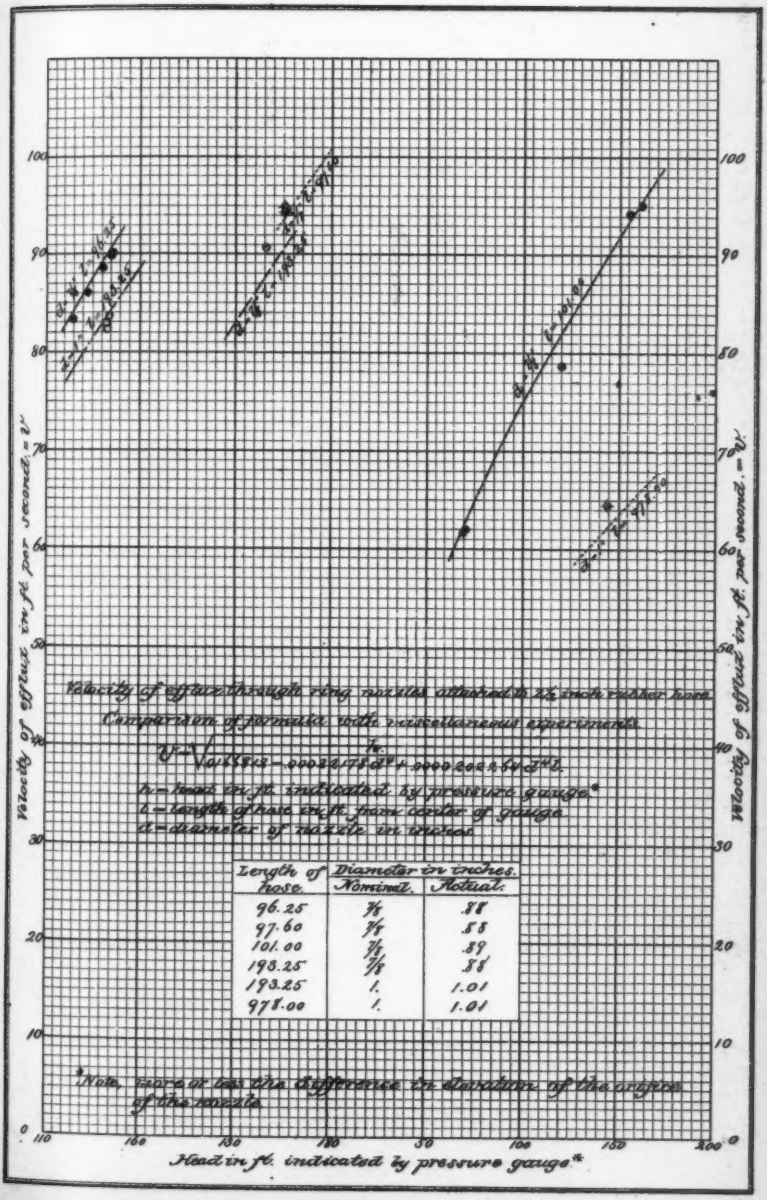
h = head in ft. indicated by pressure gauge.*
l = length of hose in ft. from center of gauge.
d = diameter of nozzle in inches.

Length of hose	Diameter in inches. Nominal.	Actual.
96.25	7/8	.88
97.60	7/8	.88
101.00	7/8	.89
193.25	7/8	.88
193.25	1	1.01
978.00	1	1.01



*Note, more or less the difference in elevation of the orifice of the nozzle.

Diagram No. 7.



Length of hose.	Diameter in inches. Nominal.	Diameter in inches. Actual.
96.25	7/8	.88
97.60	7/8	.88
101.00	7/8	.89
193.25	7/8	.88
193.25	1.	1.01
978.00	1.	1.01

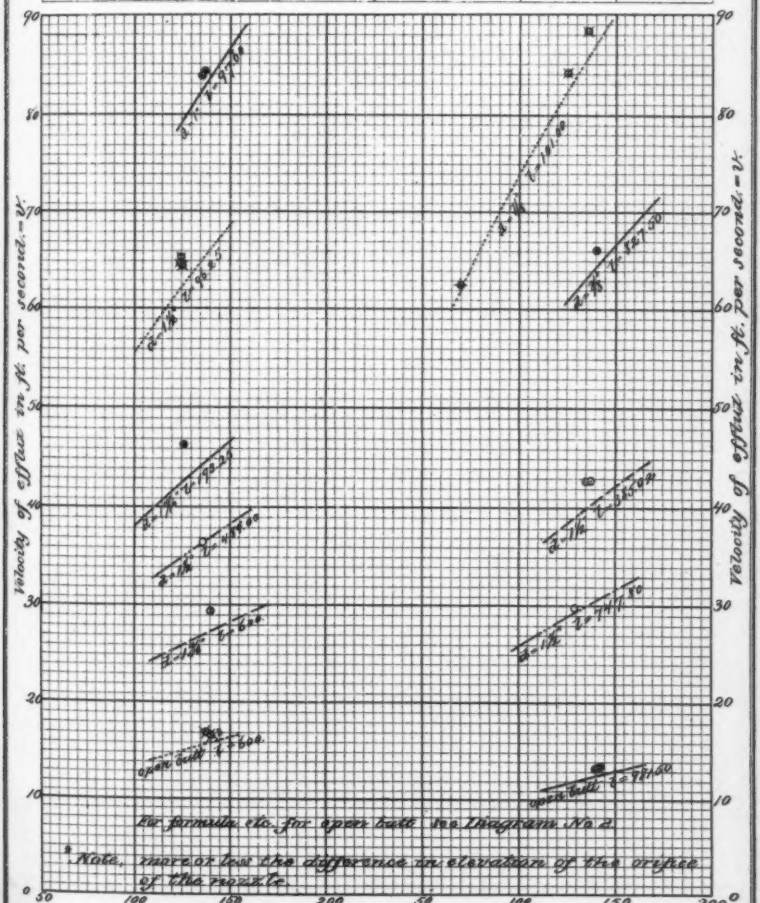
Diagram No. 8.

Velocity of efflux through smooth nozzles attached to 2½ inch rubber hose.
Comparison of formula with miscellaneous experiments.

$$v = \sqrt{\frac{h}{.0165102 - .000398\,d^4 + .000036296\,2\,d^4 l}}$$

h = head in ft. indicated by pressure gauge.*
l = length of hose in ft. from center of gauge.
d = diameter of nozzle in inches.

Length of hose.	Diameter in inches. Nominal.	Diameter in inches. Actual.	Length of hose.	Diameter in inches. Nominal.	Diameter in inches. Actual.
96.25 – 385.02	1½	1.5	193.25 – 600	1 11/16	1.6875
484 – 747.50			827.50	⅝	.575
101.00	⅞	.84	97.60	1.	1.025



For formula etc. for open bulk see Diagram No. 2.

* Note. more or less the difference in elevation of the orifice of the nozzle &c.

Diagram No. 9

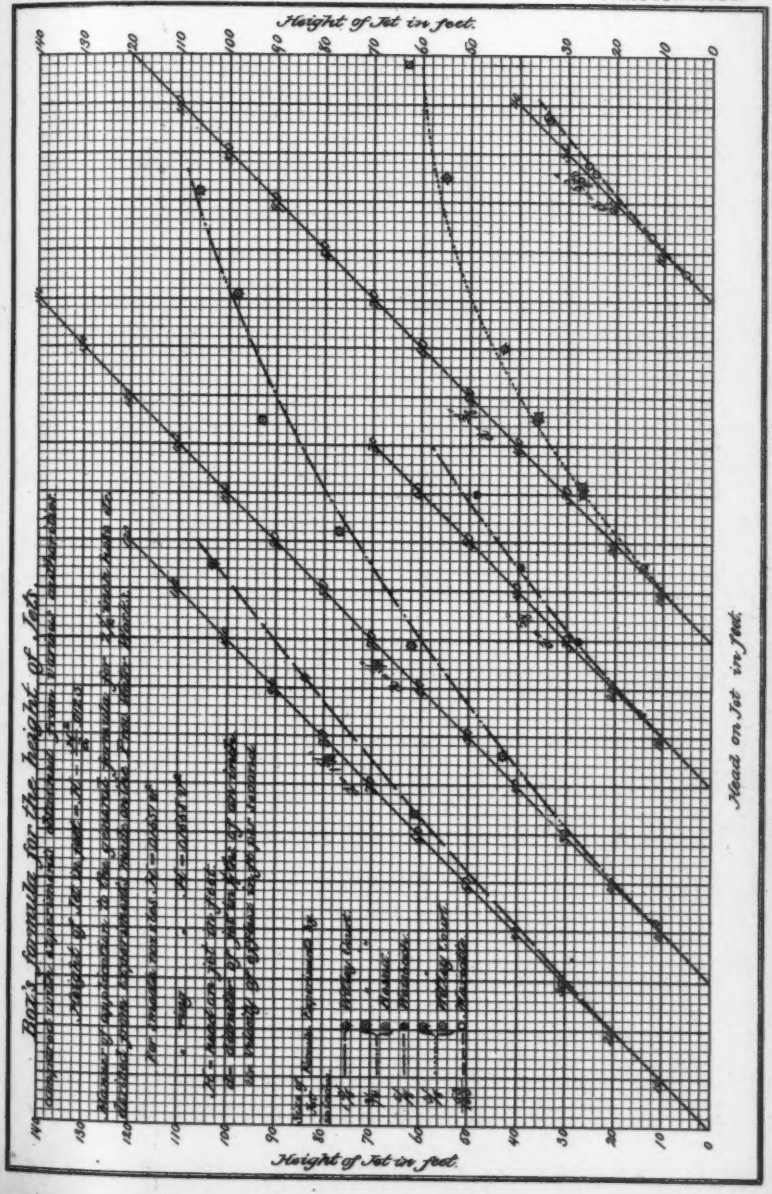

Height of Jet in feet.
Head on Jet in feet.
Height of Jet in feet.
Box's formula for the height of Jets

Diagram No. 10.

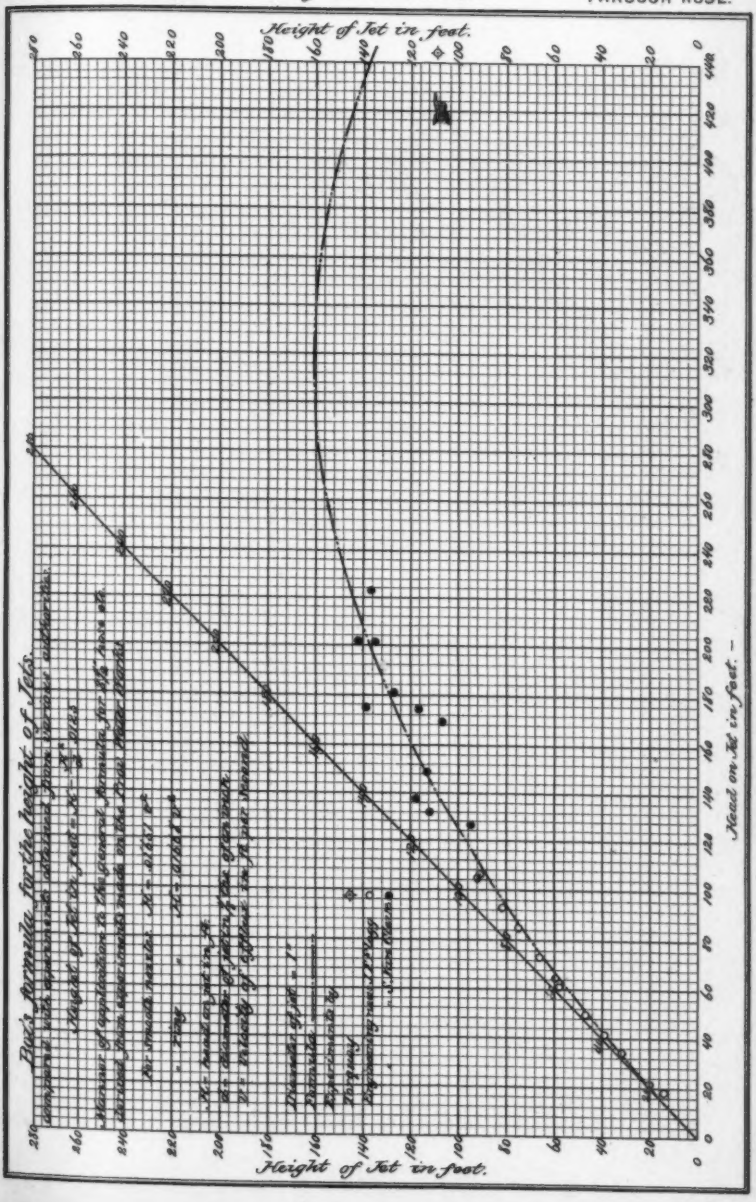
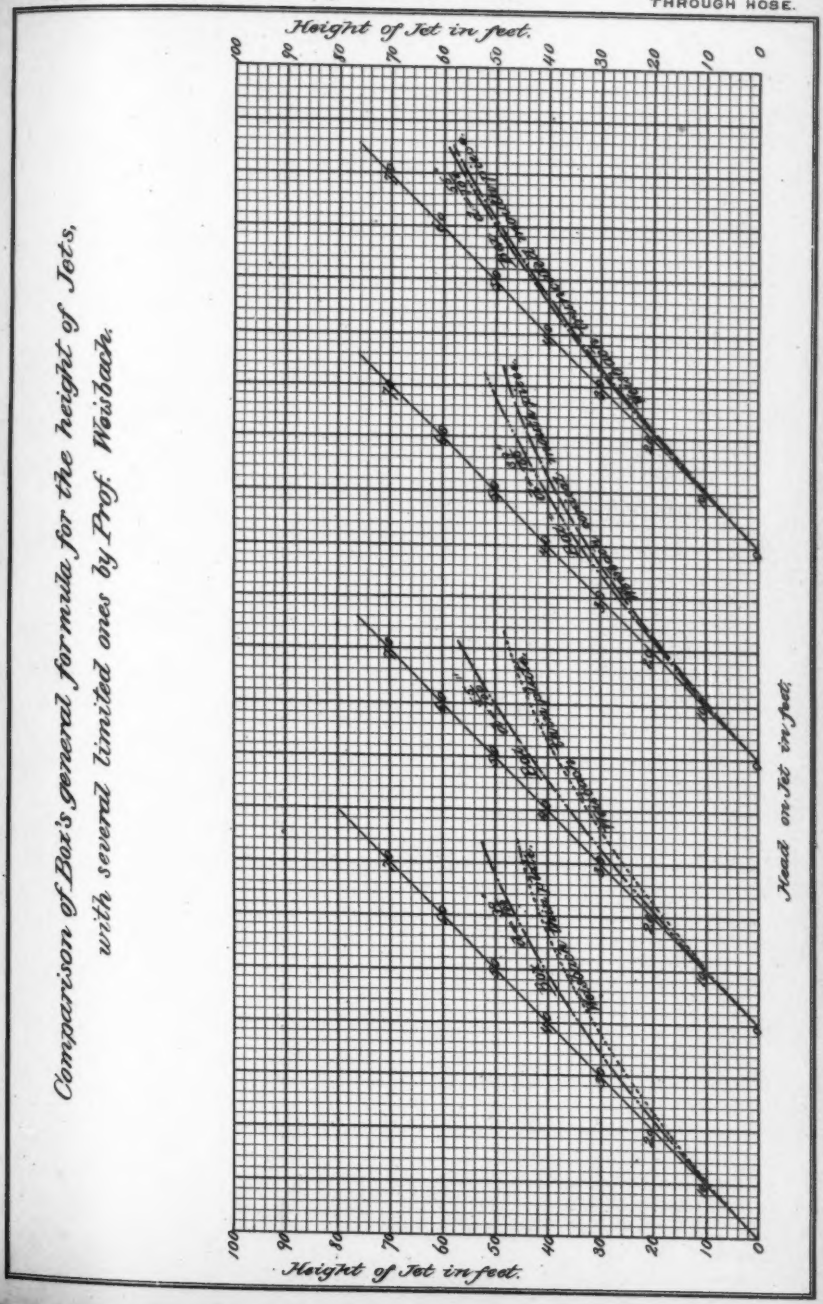


Diagram No. 11.

Comparison of Box's general formula for the height of Jets, with several limited ones by Prof. Weisbach.



can readily see if the men have been judiciously placed. It will be seen from this that the existing condition of the track is met by added forces and not by diminished length of sections, which remain fixed, unless such extensions to freight yards are made as to increase the permanent work of the section, which might render a redivision advisable.

The conditions of track sections are subject to such frequent and systematic changes, by the laying of new rails, reballasting, etc., that a redistribution of forces can often be made to the advantage of the work and in the interest of economy. Thus the section which last year required a large section force to re-lay with rail and renew with ballast, requires but a minimum force to maintain the track this present season, while those sections laying new rails and reballasting manifestly need more.

When the season for track work is past the forces are reduced, and in winter only such help as is needed for the daily routine track work of the division is retained. For any extra work, or in case of snow or any emergency that may arise, requiring little or much additional labor, the road master is empowered to put on extra forces for the speedy completion of the extra work in hand, reporting at my office at the end of each week, on a blank form prepared for that purpose, the number of extra days' labor and the kind of work performed. In this manner the efficiency of the force has been maintained with a diminished cost of labor.

Those who have been engaged in the maintenance of roadway and track know how to appreciate good section foremen. These men are generally drawn from the laboring classes, and are seldom educated beyond the point of reading and writing tolerably. Their track education depends largely upon the instructions received from their supervisor, and their individuality depends largely upon the impressions derived from constant intercourse with their superiors. In other words, the section foreman, possessed of the natural mechanical qualifications, is otherwise largely what you make him. The general rules usually issued in printed form by railway companies, for the government of section foremen, are generally sufficient to govern them in the performance of their routine duties. Having provided the foremen with this book of rules, the necessary material, and with the tools of his craft, prominent among which are the track-gauge, level and tamping bar, it becomes necessary to see that

the rules are properly understood and cheerfully obeyed, that the material receives proper care and attention, and that the tools furnished are used as directed and in a proper manner. To train the men to a conscientious and cheerful compliance with the rules, to stimulate an interest and pride in the track men as to the condition of their sections and the economy of their work, to instruct them and instill into their minds an appreciation of the importance of a proper use of their tools, is the work of those having track forces in charge; and the question arises, how can these ends be best attained? We will sometimes see the section foremen of an entire division of road so accustomed to specific orders for doing routine work, that orders are awaited when the work should be done at sight. When the order comes the work is accomplished, and the foreman awaits again the direction of the track master to direct a continuance of his work. Upon the other hand, we will find on track divisions foremen who are always at work, and most generally at the point where the work is needed. This difference comes of the manner of treatment and of a difference in training. In the first case we see the logical results of too frequent specific orders and the constant personal direction of routine details, instead of training the men to perform the work themselves; hence the men learn more and more to rely upon the judgment of the road master. In the other illustration we see the natural results of properly instructing the men in the details of their work, in a manner to cultivate a spirit of self-reliance and a sense of their responsibility. In my opinion, it is unwise for the road master to direct the routine work of the section. If the foreman is incompetent and cannot learn, he has no business to be in charge of men. If he is capable, teach him to properly direct his work; if his methods are faulty, correct them; if his judgment is defective, invigorate and perfect it. When work is not being properly done, road masters are far too apt, while on the ground, to take the direction of the gang out of the foreman's hands, instead of instructing him and requiring him to amend and perfect his modes of operation. In this manner men gradually learn to depend upon the road master in matters which they should determine for themselves, and, in the absence of the road master on that section, which necessarily must be the larger portion of the time, old systems and discarded methods will prevail. To strengthen the individuality of the foreman and lessen his dependence upon others, and to promote a self-reliant spirit, I would frequently ask him his plans of work for the morrow.

If his plans are judiciously laid, I would approve; if faulty, criticise and correct them. By this method we attain the same end as by direct instruction, and at the same time teach the men to observe and think. With this treatment foremen soon learn to plan their work ahead, to be prepared to tell you when you ask, and it soon becomes a habit. Foremen will also bring every faculty to bear upon the subject before determination, that their plan may meet with your approval, and thus avoid your criticism and correction. If any work on the section is defective by reason of oversight or neglect, do not order the defect remedied, but ask the foreman, "why it has not been done before?" The direct result upon the track will be the same. The difference in the management seems slight, but the moral effect upon this class of men is widely different and far-reaching in results. They will soon learn to watch for and detect the defects of their section and remedy the same on sight, to avoid the censure of dereliction to duty, and the road master will find that not one order is necessary where he gave ten before. I would observe the same method throughout, and in every way discourage that spirit of dependency which is much too prevalent, and stimulate the observing faculties and prompt to thought the mind of the section foreman, and he will thus become a thinking entity, instead of a mere instrument with which to execute an order. I have spoken thus minutely of the treatment of section foremen, as I have seen the good results following the course of action prescribed.

Two seasons I made a tour of my division on a hand-car, aggregating some nine hundred miles of line, examined each section and personally inspected the work of every foreman. I think the contact was of mutual benefit. I certainly became more familiar with the class, and my sympathy and admiration for them were both enlarged. The advantage gained was not confined to the trips I made, but the foremen expect me each year and prepare their track for my coming. I have found the criticisms of the previous year were never made in vain.

I am only sorry that in some years my engagements are such as to prevent my making this very interesting and profitable trip. When we consider the large proportionate cost of labor in making track repairs, we can realize how little we have done to improve the section foreman. He is, in a great measure, what he has made himself.

Inventors have taxed their ingenuity and have devised and tested many forms of fastenings to improve our joints; engineers and en-

gineering societies have devoted themselves to the discovery of some economic plan of preserving ties and timber from decay; railroads have kept careful and elaborate records of the life of rails; mechanical tests and chemical analyses have been made to determine the composition best adapted for our use; while this important factor in the maintenance of way, the section foreman, how little we have studied him! and yet upon his shoulders largely rests the work of properly caring for this material, which every branch of our profession has contributed its full share of scientific research and experience to perfect.

It is largely with a view of impressing upon the mind of the foreman his personal responsibility and individual accountability for the condition of his section, that I discontinued the use of extra gangs in the making of ordinary track repairs. Prior to making the change, the extra gang was charged with being the author of all the ills from which the section suffered, and, although the extra gang was thus made the scapegoat, it was not without some shadow of justice. An extra gang foreman has no interest in the section upon which he is engaged, excepting to complete the work laid out for him, which he frequently does with more reference to speed than thoroughness. Particularly is this the case when the point at which the men are working affords poor or expensive living accommodation for the men.

In my experience, even under the most favorable circumstances, the work was not done with that view to permanence which a section foreman has in mind. Since discontinuing these gangs, I have, when required, as stated in the first part of this paper, added men to the regular gangs, and have found the work better done, and have left no chance for the foreman to shirk responsibility concerning the condition of his section. The objection to extra gangs does not extend to construction or extra work, where they can frequently be used to advantage, but I avoid their use for regular section work as much as circumstances will allow.

This tendency to a want of thoroughness in making repairs to track, although more marked, is not confined to extra gang foremen. The importance of strict thoroughness is not understood or appreciated by nine-tenths of the section foremen, and, I may say, three-fourths of the road masters of the country. In nothing do these men need to be so fully drilled as in the importance of thorough and conscientious track work, particularly in tamping, to stand the service to which our tracks

are subjected. To track foremen the condition of the track is largely a matter of appearance to the eye, and too frequently they are led into hurried styles of work, covering too much ground in a day, often impelled by a desire to make a better showing; they are content to shovel tamp, or, if bars are used, the work is not well done, and, though the track may be very pleasant to look at, a few weeks' traffic destroys the surface, line and level, and the same track must again receive attention.

Much of our defective track is due to careless and insufficient tamping. In all cases where the track is being surfaced I require the tamping bar to be used. Insufficient bar tamping is almost invariably followed by general instability of the track, which, even while in fair level and surface, can readily be noticed while riding over it. As might be expected, the surface and level are soon destroyed, the spikes pull, ties churn, rails cut into good oak ties, and it is no uncommon thing, even on our best roads, to see the ties of one section badly cut in by the flange of the rail, while the adjoining sections, with the same general condition of road-bed, ballast and material, are almost entirely free from the evils mentioned. This, I am satisfied, is largely attributable to the difference in tamping. On the division of road under my charge we have used the tamping bar entirely for surfacing and leveling track, and, while the results were gratifying, there remained much room for improvment. The commendable desire of foremen to go over the entire section, coupled with a lack of calculation to ascertain the daily performance necessary to attain that end, even with good, ambitious, conscientious men, often leads to less thoroughness of work than I deem essential to a proper and economical maintenance of way. I found, almost invariably, that our active but slower-going foremen in the seeming amount of work performed had the best and most enduring track. I have a number of cases in my mind, but one so marked that I will mention it. The section in question is one of the hardest to maintain on the line, having many curves and a continuous heavy grade. The sections east and west were of the same general character, but in a less degree. The three sections had what one would call good section foremen, and yet the section of which I speak, although the hardest to maintain, was always in better condition than the other two. I could tell it upon the train the minute the car crossed the section line, by a firmness and stability which was quite marked in comparison. In fall and spring this section was invariably in better condition and repair

than its neighbors. An investigation showed that, in his summer work, while equally energetic, the foreman did not get over more than three-fourths the ground worked in a day on the adjoining sections, which led me to believe more thorough work was done. I have seen good, energetic, faithful foremen fail because they tried to get over too much ground. I determined to correct this evil, and for that purpose introduced the accompanying blank, and will explain the uses to which it has been put.

The blank gives a classification of section work, and provides for the record of the labor performed each day. The foremen are required, at the close of the day's work, to record the number of hours' labor performed on the different kinds of work. Blank columns are provided to be filled out in case of any unclassified labor being done. In this manner nothing has to be transcribed, and nothing is left to the memory of the foreman, thereby affording an excellent basis for the proper distribution of the pay-rolls. Under the heading of "Track Work," all time consumed in the work of general repairs is recorded, including surfacing, leveling, lining, etc. Against this, and on another column, stands the heading: "Track Completed," which shows the number of feet of track thoroughly repaired, so as to be considered finished track. Early in the season the road master selects a piece of track on each section needing an average amount of labor to put it in thorough repair. In the road master's presence the gang is worked steadily during the day, and everything is done with a view to permanence and thoroughness. At the end of the day the work is measured, and it stands as a check upon the average day's work upon the section. The foreman distributes the labor and records the track completed for each day's work, and at the end of the week, the blanks being filled, they are returned to the road master, by whom they are examined and irregularities noted.

A recapitulation of the week's work on each section is returned to me for examination and comparison. If the amount of work done exceeds the recorded average, one of two conditions will be found to exist: either the amount of work required at the point in course of repair is less than an average of the section, or else the work is being less thoroughly done, which can be determined by the personal inspection of the road master or the engineer. If, on the other hand, the track completed shows to be less than the average, either the amount of work to be done is greater than the average, or the time and labor of the men

THE LAKE SHORE & MICHIGAN SOUTHERN RAILWAY COMPANY.

CHIEF ENGINEER'S DEPARTMENT.

DISTRIBUTION OF LABOR.

Of.....Section,.....Division, for the Week ending.....day of.....188....

Date of Month.	Day of Week.	Number of Men.	Number of Days.	NUMBER OF HOURS' WORK PERFORMED.																										
				Repairs Road-bed and Track.											Repairs Fences.		Repairs Bridges.									New Ditches Dug, Feet.	Ditches Cleaned, Feet.	New Ballasting.		Feet of Track Completed.
				Track Work.	Laying Rails.	Repairs Side Track.	Putting in Ties.	Ballasting—Shimming.	Scurfing, Handling Snow.	Ditching.	Track Watchman.	Extra Work.		New Side Track.	Fences.	R. Crossings and Signs.	Bridges.	Culverts and Cattle Guards.	Water Supply.	Telegraph.								Length, Feet.	Raised, Inch.	
	Sunday....																													
	Monday..																													
	Tuesday....																													
	Wednesday.																													
	Thursday...																													
	Friday.. ..																													
	Saturday...																													
	Totals.....																													

The Foreman will report on this blank the different kinds of work performed, stating the number of hours of each kind of work, under the respective heads, and forward this blank to the Trackmaster at the end of each week, and last day of each month.

.....*Foreman.* .....*Trackmaster.*

have not been fully utilized or have been misdirected by the foreman. Again, an examination by the road master will reveal the fact, and the want of thoroughness in the one case, or the dereliction of duty in the other, will be discovered, and can be remedied at once.

An examination of the blank will show that, if other than track work is performed, which would reduce the amount of track completed, it will be recorded under its proper head upon the blank, so the average work completed per man per hour can always be determined. The advantages of such a blank are manifold. It enables a comparison of the methods and direction of the work by the most successful foremen with those whose standing is not so high, although, perhaps, equally as ambitious and faithful. It also gives an office record of the progress of the season's work, and if any construction work is contemplated it can be readily ascertained if the regular forces can be used to advantage, or if the use of extra gangs is expedient. It also assists in the placing of men and the distribution of forces by aiding the judgment and the eye with a presentation of figures showing the actual progress of the season's work.

Each week I require the section foremen to report the number of track bolts tightened between mile-posts on their respective sections, giving the style of lock or washer used on the bolts so tightened. This report gives me at all times data for comparison between the various locks and washers, besides leading to an improvement in the condition of our joints. Under the same rules, and with the same instructions, I find the bolts have been more carefully watched since I thus required the foremen to put themselves on record.

In the working of section gangs, I would recommend that the force be started at the poorest part of the section and be required to work to some definite point, finishing everything as they go; and certainly, in my experience, those road masters who have followed this plan the closest have been the most successful. It may be necessary, at times, to deviate from this line of action and do scattering work on the section, but this working a little here, there and everywhere should be avoided as much as possible and the work carried on continuously. Section foremen, as a rule, when instructed to work in the manner stated, are generally skeptical of the result, because of their poor calculation. When they see the short piece of track completed in a day, they regard it as an almost hopeless task, but, as the work of each succeeding day is

added, they take new courage, and when the first month's work is done they seem imbued with a strong desire to finish to the end. The moral effect upon the men, to say nothing of the advantage of systematic work, is excellent. Track thus repaired is definitely located, and by the aid of the report heretofore mentioned, the condition of completed or finished track can be examined and its riding and lasting qualities determined, from time to time. If defects are discovered, the cause can be ascertained and the foreman instructed to do better, or if the result of incompetence, the foreman can early be removed, leaving the best part of the season to his successor, while it too often happens that changes are not made until late in the season, when additional material and increased forces are required to make amends for the misdirected labor of the summer months.

In using blanks, statements of material used and of labor performed should never appear together. Foremen have the impression, in filling out such blanks, that the more material used for a certain amount of labor, the better is their record, and a wasteful use of material is liable to result. In re-laying ties this is very noticeable, it being much easier and involving less labor per tie to take a number out together than to simply remove the ties that should be removed. Foremen sometimes take out ties good for two or three years, because a better showing for their labor can be made, and the too free use of ties at one point results in a too sparse use at another, or in a waste of ties and money. Foremen should be trained to take out all poor ties and to let all others remain, and to exercise the same thought and economy in handling the company's material as in the management of their own households. In educating the men to a judicious use of ties, perseverance and much patience will be required, as they frequently go from one extreme to another, but when once attained, a better tied road, at less cost, will amply repay your efforts. A good corrective is to pile the old ties upon the right of way, and to have the piles examined by the road master before burning, while the ties remaining in the track are constantly before his eyes for inspection, and the correctness of the foreman's judgment can be determined.

I hope the suggestions in this paper may draw out criticisms and suggestions from those experienced in this line of work. Mr. W. P. Shinn, in his able paper upon "The More Efficient," etc., gives the average cost of labor for five years, 1878–1882, on the track repairs of the Pitts-

burgh, Fort Wayne and Chicago Railway, as being $3\frac{16}{100}$ cents per engine mile, while the cost of rails was only $1\frac{79}{100}$ cents per engine mile. We all know that labor constitutes the greater part of the expense in track repairs, and certainly the proper direction and management of that labor is worthy of our attention. For my part, I have found it one of the most perplexing problems to attain the full measure of efficiency at a minimum cost for labor. None can appreciate the anxiety of mind so often experienced in working large numbers of men, scattered over a long line of railway, until he realizes that upon the sobriety, intelligence and conscientious attention to duty of these men the safety of so many lives and property depends. Of necessity, the greater part of the section man's work and responsibility must come to him when unaided by his superior's judgment and experience, and to meet those duties properly, and to make foremen as efficient in our absence as in our presence, it is clearly our duty to preserve the track man's manhood, promote his self-reliance, better his judgment and improve his understanding, and when this has been accomplished the reward will come with more efficient service and reduced expenses.